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WALNUT CULTURE IN CALIFORNIA

BY

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WALNUT CULTURE IN CALIFORNIA[1]

By L. D. BATCHELOR

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[1] Paper No. 82, University of California, Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, California.

PREFACE

The present bulletin represents the results of general observations and specific investigations of the writer and his associates. The subject matter and the method of presentation have been chosen in response to the numerous inquiries relating to general walnut culture, which have been received during the past six years.

The writers' thanks are extended to Mr. Carlyle Thorpe, Professor F. T. Bioletti, and Dr. H. S. Reed for their careful criticism of the manuscript, and to Mr. D. C. Wylie, of the California Walnut Growers' Association, for his able assistance in gathering much of the general information in the walnut groves and among the walnut growers in various parts of California. Use has been made of the Experiment Station Bulletin 231, by Professor Ralph Smith, and of "The California Walnut," by Mr. W. T. Webber and Mr. W. E. Goodspeed.

For a more detailed discussion of the several ramifications of this subject, such as history, nursery propagation, and the description of rarely found varieties and diseases, the reader is referred to Smith, R. E., Walnut Culture in California, Univ. of Calif. Bull. 231, 1912, and also to Lake, E. R., The Persian Walnut Industry of the United States, U. S. Dept. of Agr., Bur. Plant Ind., Bull. 254, 1913.

GENERAL REVIEW OF THE WALNUT INDUSTRY

The Persian walnut (*Juglans regia*) or, as it is more commonly known, the English walnut, may be seen growing in nearly every county in the state of California. The commercial production of nuts, however, is centered mainly in southern California in the following four counties, mentioned in the order of importance: Los Angeles, Orange, Ventura, and Santa Barbara. Riverside and San Bernardino counties have a considerable area of young groves; and in the central part of the state walnut culture is gradually becoming important in the following counties: Santa Clara, San Joaquin, Contra Costa, Napa, and Sonoma.

Figure 1 shows a map of the state and the relative importance and distribution of the crop in the several counties.

At the present writing, there are approximately 85,000 acres of walnut trees of various ages within the state. The annual production for the state during the last ten years may be seen from the following table:

TABLE I

Annual Production of Walnuts in California
(Expressed in pounds)

1911	25,000,000	1916	29,200,000
1912	22,500,000	1917	33,000,000
1913	22,700,000	1918	40,231,000
1914	17,800,000	1919	56,200,000
1915	29,650,000	1920	43,000,000

BUSINESS PROSPECTS OF THE INDUSTRY

The present condition of the industry indicates that walnuts may continue to be one of the most staple and at the same time most profitable crops which can be grown on land, and in locations, adapted to this crop. The annual consumption of walnuts in the United States has ranged between 60,000,000 and 70,000,000 pounds annually during the past five years, and has increased more than 30 per cent since 1909. Nuts, which were formerly looked upon as a holiday luxury, are becoming more and more a food to be used the year through in the average household. This increase and wider use of the walnut has been accompanied by an increase in importation exceeding our own average production, and a gradual increase in the prices paid to the California grower. It may thus be inferred that the business of walnut culture in California is not likely to suffer from the results of over-production in the near future. It is difficult to forecast future economic conditions relating to the production and sale of any particular crop. Nevertheless, many of the older walnut growers, who have known this industry from its early days, believe that the planting of a walnut grove at present is as safe an investment as it has been at any time during the development of the industry.

LENGTH OF LIFE OF WALNUT TREES

The limit of the profitable length of life of a walnut grove cannot be told from experiences in California. Provided the soil, climatic, and water conditions are well suited to this crop, the trees may continue to thrive and produce satisfactory crops for a long period, which is difficult to limit. Some observers have expressed opinions that walnut groves, under favorable conditions, may continue to be a satisfactory source of revenue until the trees are from 50 to 200 years old. Some of the oldest walnut groves in Ventura County are the most profitable and productive in the state. Notable examples of such old, yet productive groves, are the J. C. Daly grove of 20 acres planted in 1881; 18 acres of the J. M. Sharp grove planted in 1887; and the

T. A. Kelsey grove of 26 acres planted in 1888. The last mentioned grove has only 12 trees to the acre, planted 60 feet apart each way, and is considered by many to be one of the best walnut properties in the state of California. The trees, at their present age of 34 years,

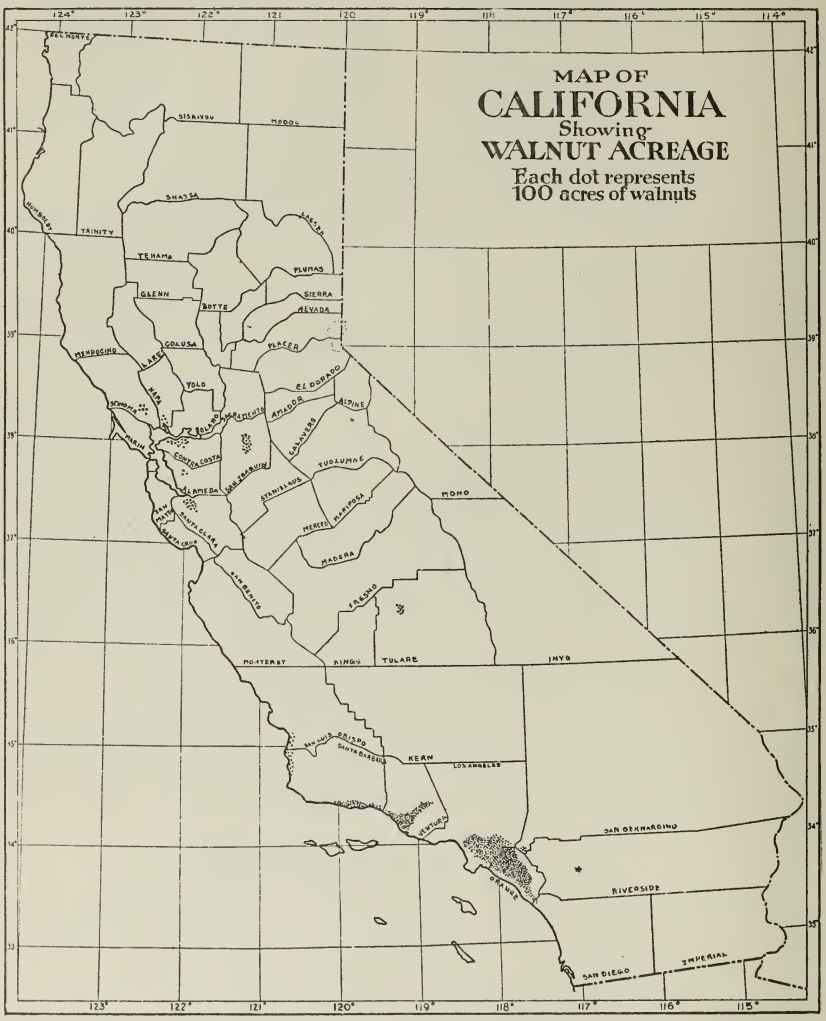

Fig. 1. (From "The California Walnut.")

show no apparent deterioration. This grove has produced an average annual tonnage of 1941 pounds of nuts per acre during the past four years. Groves in which the trees are planted 60 feet each way may be expected to grow longer without deterioration than groves where the trees are planted closer and thus severely compete with each other.

PROFITABLE BEARING OF YOUNG TREES

The young walnut grove may be expected to bear profitable crops by the time the trees are 6 to 10 years old, depending upon the variety, the number of trees planted per acre, and the natural conditions surrounding the grove.

A grove of almost 50 acres of the Placentia variety in Orange County produced an average of 44 pounds of ungraded nuts per tree in its ninth year. As the trees are 60 feet apart this represents 528 pounds per acre. During the first 10 or 12 years this might well have been double planted and thus produced approximately 1056 pounds per acre the ninth year.

In 1918 a block of 60 trees of the Chase variety, on a heavy clay loam soil in the Puente district, produced a profitable crop of 35 pounds per tree in the sixth year. The records of these groves and of a grove of 38 Ehrhardt trees are shown in Table II.

In considering this table one should keep in mind that each of these plantations is growing under the best natural and cultural conditions, and is thus without doubt considerably above the average. In projecting a business enterprise, the yields shown may be looked upon as approaching the maximum possibilities and should therefore be discounted 25 to 50 per cent to reach a figure which may reasonably be expected to prevail under average conditions. Again, the figures here presented are of little value in making comparisons between the three varieties in question, as no two varieties were of the same age the same season.

TABLE II

AVERAGE YEARLY PRODUCTION PER TREE OF YOUNG WALNUT GROVES

	Variety					
	Placentia		Chase		Ehrhardt	
Year	Season's growth	Yield in lbs.	Season's growth (Ungraded nuts at harvest)	Yield in lbs.	Season's growth (Ungraded nuts at harvest)	Yield in lbs.
1915	7th	22†	----	----	10th	80
1916	8th	27†	----	----	11th	76
1917	9th	44*	5th	18	12th	79
1918	10th	43*	6th	35	13th	81
1919	11th	104*	7th	72	14th	117
1920	12th	82*	8th	43	15th	98

* Pounds of uncured and ungraded nuts at harvest.

† Pounds of cured and ungraded nuts at harvest.

Although the cultural and natural conditions in all these groves were favorable, the plantings are several miles apart and conditions were not identical. Certain seasons are particularly favorable to crop production. The year 1919 was characterized by especially abundant crops of walnuts. These were followed in many cases by lighter crops in 1920, although the young trees were one year older and had a greater bearing surface.

CLIMATIC REQUIREMENTS

The chief climatic limitations of the walnut are frosts in spring and fall, and extreme heat in summer.

FROST INJURY

Low frosty sites should be avoided for walnuts. A temperature of even 2 or 3 degrees below freezing (32° F.) will usually kill a large percentage of the young walnut flowers, if they are just starting to bloom. During the season of 1920, late spring frosts during the second week of April reduced the walnut crop to a great extent in several of the inland valleys. In one instance at least, the absolute minimum recorded by a reliable thermometer was only 29° F., yet it was estimated that 50 per cent of the crop was destroyed. During this period apricots and the earlier blooming cling peaches in adjacent orchards, were about the size of green peas, and experienced little or no injury.

During the morning of April 6, 1921, a minimum temperature of 27° F. was experienced by a seedling walnut grove in which the majority of the trees were in full bloom. This temperature prevailed for about an hour and apparently destroyed nearly the whole potential crop, except in the tops and centers of the trees, where an occasional cluster of blooms escaped injury.

As a general rule, the late blooming varieties, such as the Eureka and Concord, may be expected to escape injury from the late spring frost more consistently than the earlier blooming soft-shell types. During the spring of 1915, however, walnut twig tips and young nuts were killed during the first week in May on some of the low sites in Los Angeles County. With a frost as late as May the late blooming varieties may suffer more injury than the earlier ones, as the young nuts (one half-inch or more in diameter) of the early blooming varieties, at this time, will stand more cold than the blossoms of the late varieties. The late bloomer does not, therefore, always escape late spring frosts. It is much better to avoid planting walnuts on land which is considered too frosty for peaches during the majority of

seasons. The varieties of the soft-shell type bloom about the same time as the Bartlett pear and are not nearly so resistant to frost injury of the blooms.

Early fall frosts also cause injury, especially to young shoot growth; though this injury may not be apparent to the casual observer until the following spring, when the tree fails to leaf out on the major portion of the past season's growth. This type of injury is more fully treated under the subject of die-back. It may suffice to explain here that early fall frosts prematurely stop the final ripening process of the twigs by killing the leaves. Such injured leaves will usually fall off within a week after the frost injury, whereas they might otherwise have functioned normally a month or six weeks longer. The bare, immature twigs dry out rapidly and sunburn on the south side during the winter months, killing back several inches, or possibly several feet to the more mature wood, which has been able to withstand the abnormal insolation.

HEAT INJURY

The chief injury to the walnuts during the extreme hot weather of the summer months is the sunburning of nuts on the outsides, tops, and south sides of the trees. Such burned nuts usually become "blanks" if the injury occurs during June or July. If the sunburning takes place when the nuts are more fully developed, in August, they may be salvaged as culls with a portion of the kernels edible. In mild cases of sunburn injury, a small part of the husk may stick to the shell or may only stain it, causing the nut to be graded out as a cull. The kernels of such nuts may be of first quality, although it is likely that there will occur a high percentage of amber and black kernels and partly shriveled and mouldy meats among this class of nuts. Nuts on trees growing on a deep silt soil withstand the extreme heat without burning much better than nuts on trees growing on a shallow soil with less moisture available. Sandy soils must be frequently irrigated in the hot sections if the walnuts are to avoid serious injury by sunburning. At a maximum temperature of 100° F. in the shade, accompanied by low humidity, walnuts which are exposed to the direct rays of the sun may be expected to sunburn. This temperature, or higher, occurs in many of the inland valleys, 15 to 30 days during the summer months. Under such conditions the crop is always injured by sunburn. Regardless of this, the planting of walnuts is extending more and more inland. The planting of oranges is restraining the development of walnut groves on the coastal sections. At the present time walnut groves have not become as productive in the

inland valleys, which experience frequent summer days with maximum temperatures of 100° F. and over, as they have been nearer the coast, where the weather is characterized by a smaller daily range and a lower maximum temperature. Varieties especially selected for the hotter sections may tend to correct this difficulty in the future. In the past, most of the walnuts planted inland have been of the same varieties as those which were originally selected for the coastal regions. Varietal adaptation is more fully treated under the heading of varieties.

At present walnut culture is most successful in the sections of the state which are characterized by a long growing season free from frosts, where the daily range in temperature is not great, where the absolute maximum seldom goes above 100° F., and where winter temperatures are moderate and the humidity is high, especially during the summer. Sudden changes in temperature, such as occur in the desert regions, seem decidedly detrimental to the growth of the walnut tree. The localities where favorable climatic conditions occur is indicated by the fact that the largest walnut shipping centers in the state are Santa Ana, Whittier, Puente, Saticoy, and Santa Barbara.

When the tree is fully dormant, the absolute minimum temperatures of winter, during January and February, apparently have very little to do with its welfare. This is especially true of the French varieties. Trees of the Mayette and Franquette varieties have grown for some years without severe winter injury along the west side of the Wasatch Mountains north of Salt Lake City, Utah, where the minimum temperature occasionally was 5° below zero (Fahrenheit) during the winters of 1913–14 and 1914–15.

SOIL REQUIREMENTS

DEPTH AND CHARACTER OF SOIL

The success of walnut culture is dependent upon favorable soil conditions to a greater extent than that of many other tree crops. A well-drained deep silt loam, containing an abundance of organic matter, free from a high or fluctuating water table, hardpan, sandy subsoil, and "alkali," is essential for a first-class walnut grove. Shallow soils underlaid by a hardpan or an impervious clay stratum within 5 or 6 feet from the surface will produce only a short-lived, second-rate walnut grove. Such groves are frequently stunted in growth, subject to yellowness, and are poor producers.

There are a few moderately successful groves growing in fine silt soil underlaid with fine sand within 4 or 5 feet from the surface, but such properties require the greatest skill in planning the cultural

and irrigation practice and should certainly be avoided by the beginner in walnut growing.

Very light sandy soils are usually unsatisfactory, producing slow-growing, stunted, poor-yielding trees. On such soils the nuts are very subject to sunburning. One should not judge the soil conditions entirely by the surface soil. The nature of the subsoil may be of great importance. There are first-class walnut groves in the El Monte district growing, apparently, in a very light sandy soil. The soil changes, however, in some instances 3 or 4 feet from the surface, grading into a silt loam which seems to be an ideal soil for walnut roots.

Very heavy adobe soils or silts underlaid by adobe are not best suited to walnut groves. The trees on such soils are usually stunted, making very little growth and fruit wood in the tops when mature. These soils are difficult to cultivate, and it is difficult to obtain a deep penetration of the irrigation water which is so essential to good walnut culture. Such soils frequently contain amounts of alkali harmful to walnuts, and their leaching by any system of irrigation is very difficult.

DRAINAGE AND ALKALI INJURY

A water table within 9 or 10 feet from the surface of the soil may make it impossible to maintain a profitable walnut grove. Most of the high water tables in arid regions are characterized by carrying more or less "alkali"[2] in solution. The mere presence of water within 9 or 10 feet of the surface is usually only part of the difficulty, the alkali present is the greatest concern, for the deep-rooted trees obtain a portion of their water from this water table and may be injured by the salts therein, even though there is a seemingly sufficient layer of good soil above the water. There occurs an instance in Orange County where an old grove has been practically ruined by a rise in the water table to within only nine feet of the surface. This water contains 700 parts per million of salts. The water rises approximately 6 feet by capillary action in the soil; thus there is only a 3-foot depth, or one-third of the soil, above the standing water, which is not impregnated with salts. Several instances were noted in Ventura County during the fall of 1919 where walnut trees were severely injured by the presence of an "alkali" ground water 9 to 13 feet from the surface. When the trees were planted 20 years ago in this district, the water was at least 30 feet from the surface. It is difficult to place a definite safe boundary beyond which injury from a high

[2] For a discussion of alkali in the irrigation water see page 152.

water table is likely to occur. Apparently quite as much depends upon the nature of the water as upon the actual depth from the surface, within the limitation of the root zone. The rainfall, irrigation practice, and nature of the soil, and the irrigation water may also greatly influence the limitations, for walnut culture, of land with a high water table.

Rarely there is found an exception to the rule of injury resulting from a high water table. There is one notable example in Santa Barbara County where an orchard is sub-irrirgated by a natural flow of water from the hills. Judging from the appearance of the trees, this ground water contains no (or an exceedingly small amount of) "alkali," a condition which is exceptional to the usual shallow water tables in irrigated areas of the arid west.

WATER SUPPLY

In most of the California walnut districts, irrigation is necessary. The amount of water to be applied and the seasons of application naturally depend upon the rainfall, the amount of evaporation, the nature of the soil, and other factors. The walnut tree can not be expected to yield profitable crops unless furnished with an abundant supply of water during the entire year.

AMOUNT OF IRRIGATION WATER NECESSARY

From 12 to 24 acre-inches per acre[3] of irrigation water is usually applied to bearing walnut groves, varying according to some of the conditions related in the preceding and the following paragraphs.

[3]For those not familiar with the various methods of measuring water, the following explanation and table is offered converting miners' inches to acre inches. An acre inch of water is the quantity of water required to cover one acre to a depth of one inch.

50 California "miners' inches" = 1 cubic foot per second.

1 cubic foot per second = 7.48 gallons per second.

TABLE

Miners' inches to acre inches.

Hrs.	Miners' Inches 1	2	3	4	5	6	7	8	9	10
1	.0198	.0396	.0594	.0792	.0990	.1188	.1386	.1584	.1782	.1980
2	.0396	.0792	.1188	.1584	.1980	.2376	.2772	.3168	.3564	.3960
3	.0594	.1188	.1782	.2376	.2970	.3564	.4158	.4752	.5346	.5940
4	.0792	.1584	.2376	.3168	.3960	.4752	.5544	.6336	.7128	.7920
5	.0990	.1980	.2970	.3960	.4950	.5940	.6930	.7920	.8910	.9900
6	.1188	.2376	.3564	.4752	.5940	.7128	.8316	.9504	1.0692	1.1880
7	.1386	.2772	.4158	.5544	.6930	.8316	.9702	1.1088	1.2474	1.3860
8	.1584	.3168	.4752	.6336	.7920	.9504	1.1088	1.2672	1.4256	1.5840
9	.1782	.3564	.5346	.7128	.8910	1.0692	1.2474	1.4256	1.6038	1.7820
10	.1980	.3960	.5940	.7920	.9900	1.1880	1.3860	1.5840	1.7820	1.9800
11	.2178	.4356	.6534	.8712	1.0890	1.3068	1.5246	1.7424	1.9602	2.1780
12	.2376	.4752	.7128	.9504	1.1880	1.4256	1.6632	1.9008	2.1384	2.3760

Acre Inches

The amount will vary with the nature of the soil, as an open sandy soil requires more water to produce equivalent crops than a compact silt loam. Closely planted and old bearing groves will require more water than young groves or those with fewer trees to the acre, other things being equal.

The rainfall varies from season to season and in some years it may be necessary to apply 50 per cent more water than in others. There is considerable variation in the average rainfall of the different districts. A soil in Santa Barbara County might be thoroughly moistened at the beginning of the growing season, owing to the previous winter rains, to a depth of 8 or 10 feet, while a similar soil in Riverside or in San Diego County might be wet to a depth of only 3 feet. Obviously, the irrigation requirements of the following season would be quite different in the two cases. Table III shows the average rainfall in several of the sections where walnuts are grown.

TABLE III

Showing the Normal Rainfall in Several Walnut Growing Sections

Place of observation	Normal annual rainfall in inches
Los Angeles	14.6
Napa	24.3
Pomona*	19.2
Riverside	10.6
Santa Barbara	17.1
San Diego	10.0
San Jose	16.8
Santa Ana (Irvine)	13.3
Santa Rosa	32.0
Stockton	14.6

While the amount of seasonal rainfall may be taken as a good indication of the amount of irrigation water necessary to supplement it, it should be borne in mind that other factors, such as frequency, duration, amount of individual rains, run-off, and season of occurrence, must also be considered, as they influence the proportion of the total precipitation which penetrates into the soil and is available to the walnut trees.

The water requirements are higher in the warm inland valleys, with their very low humidity and high temperatures during the growing season, than in the coastal regions, with their cooler summers and many foggy days.

* Average of 8 years, 1913 to 1920 inclusive.

It may be said, therefore, that the walnut grower in some of the southern and central inland districts should be provided with a water right of 24 acre inches per acre per year, and that from this maximum the requirements diminish until in some individual and exceptional cases in Santa Barbara, Santa Rosa, and Napa counties walnuts may be grown successfully without any irrigation.

IRRIGATION WATER OF GOOD QUALITY ESSENTIAL

The quality of the irrigation water for walnuts is as essential as the quantity. Relatively small amounts of the "alkali" salts carried in the water are decidedly harmful to walnut trees. From many observations made during the past five years, it seems that the walnut tree is the most sensitive to alkali injury of all the orchard trees grown in California. The minimum amount of salts which will prove toxic to walnut trees will depend upon so many factors, such as the nature of the soil, the under-drainage, the rainfall, etc., that it may be impossible to state the exact maximum amount of salt which might be applied with the water without injury. In the districts of heavy rainfall and in well under-drained groves, water of poor quality could no doubt be used longer without harm to the trees than in the more arid regions, especially where hardpan exists. It is definitely known that walnut groves have been injured severely by the use of irrigation water containing only 340 parts per million of one or more of the so-called "alkali" salts.[4]

The particular salts which the water contains may have as great a bearing on the injury as the type of soil and other natural conditions of the orchard. It is impracticable to include a prolonged discussion of the effect of alkali on walnuts in this publication; suffice it to warn the present or prospective walnut grower of the importance of a water supply of good quality before continuing or establishing a walnut plantation. It is especially important in projecting new plantings to have the prospective water supply analyzed[5] and an expert opinion given upon its suitability, before proceeding to develop the property.

[4] For a discussion of alkali salts in irrigation water, see Kelley and Thomas, "The Effects of Alkali on Citrus Trees," Univ. of Calif. Experiment Station Bull. No. 318, 1920.

[5] The University, through its division of Plant Nutrition at Berkeley or the chemical division of the Citrus Experiment Station at Riverside, is prepared to analyze irrigation waters free of charge, and give an opinion on their suitability for irrigation purposes.

VARIETIES

The original walnut plantings in California were "hard-shell" and "paper-shell" seedlings. From these early plantings, the next generation of nuts produced a nut commonly known as the Santa Barbara soft-shell. The vast majority of the seedling walnut groves now growing in California consist of this variety.

From these latter seedlings many superior trees have been noted during the past 15 or 20 years. From some of these, through propagation by grafting and budding, (in a way similar to that of the origination of standard varieties of fruits, such as peaches, apples,

Fig. 2.—Effect of application of alkali water. Grove on left used water of high salt content, that on right, good water.

oranges, etc.), new varieties of walnuts have arisen. The varieties which trace back to the class of seedlings just discussed comprise the vast majority of the sorts now planted in southern California, with the exception of the Eureka variety, a brief history of which is given under the description of this variety. Some of the walnut varieties commonly planted in central California, such as the Concord, Franquette, and Mayette, have still another origin, which will be discussed under the heading of each respective variety.

The varieties of walnuts chosen for planting in California should be those most marketable, most productive, and best adapted for growing under the local conditions in question. At present, there are comparatively few varieties which have won and retained their popularity with the growers and the marketing trade. Many new varieties

have been originated in California during the past twenty years, but most of them have been propagated only in a very limited way, and have soon fallen into disfavor, owing to some particular shortcoming. New varieties of the future should be a decided improvement upon our present sorts; otherwise they are not worthy of even limited propagation.

The principal economic advantages which a grafted or budded grove of the best varieties possesses, in comparison with a seedling walnut grove, are (*a*) the budded nuts sell for a higher price than the seedlings;[6] (*b*) a grafted grove is more uniform and has fewer unproductive trees than a seedling grove; and (*c*) the seedlings are more susceptible to blight than are certain varieties which are budded or grafted.

There probably is no one *best* walnut variety for planting in the whole state of California. With the varying soil and climatic conditions, the success or failure of a variety may depend upon the question of its adaptation to the specific conditions. In reading the discussion of the varieties in the following pages and the recommendations which are made for planting in the several localities, it should be borne in mind that the observations concerning the varieties have been very general. In many instances an attempt has been made to present the consensus of the opinions of several observers, such as walnut growers, packing-house experts, and nursery men, and, although the varieties described seem to be the best for commercial planting at the present time, they may be supplanted in the future by varieties entirely unknown at present, or by varieties which may not be highly thought of at this date. The selection of varieties for propagation by grafting and budding has gone on for so short a period (15 to 20 years) that improvements may be confidently expected in the future.

In considering the varieties to plant, one should select only those which meet the requirements for a first-class commercial nut to be sold in the so-called "budded" grade.[7]

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[6] The average price for seedling walnuts sold by the California Walnut Growers' Association during the 12-year period, 1909 to 1920, inclusive, is, for No. 1 soft-shell nuts, 18.2 cents per pound. During the same period, Fancy Budded nuts averaged 21.3 cents per pound.

[7] At present only a portion of the varieties of the California walnuts are sold at wholesale under their varietal names. The Eureka, Franquette, Mayette, Payne, and Concord are sold at such; the Placentia, which comprises a greater bulk than all other grafted varieties combined, is sold under the general term "budded."

As the "budded" nuts are graded in the packing houses of the California Walnut Growers' Association, they pass through a large galvanized iron cylindrical grader, 10 feet long and 40 inches in diameter. This grader, which revolves slowly, at a 6-inch pitch, has a capacity for propely grading about one and a half tons of nuts per hour by passing them over somewhat less than 8000 $1\frac{3}{16}$-inch

A heavy shell and a firmly sealed nut are essential to withstand the handling in the grading, packing, and commercial operations without cracking open. A nut which is partly cracked open soon becomes rancid and must, therefore be eliminated from first-class grades. The proportion of kernel to the total weight in a sample of carefully graded nuts is slightly less than 50 per cent.

DESCRIPTION OF VARIETIES[8]

(Described in order of their popularity in 1920.)

PLACENTIA

The Placentia may at present be considered the best variety of walnut which has been proved thoroughly successful, commercially, in southern California. At present most of the nuts sold in the "budded" grade are of this variety. The defects of this variety will be stated first, and its good qualities later.

Probably the greatest defect of Placentia is its pronounced susceptibility to blight. During 1915 and 1916 many of the Placentia groves blighted as badly as the average seedling groves, although from 1917 to 1920, when there was little blight, this variety was particularly profitable. The second defect is the tendency of the nuts to spring open at the apex if they are dried too rapidly by exposure in the sun during the curing process.

The variety is readily propagated by grafting upon the black walnut, making a thrifty, rapidly growing tree. The Placentia usually bears young in southern California, and produces very good crops. It is regular in its bearing habits and lacks the tendency of some sorts to bear every other year. The nut has the desirable size for commercial sale, being oval, with a fairly smooth shell. The nuts tend to vary in form, and some strains are more nearly round and somewhat roughened. The nuts are not well sealed. The shell is thin, but strong. The kernel is smooth, plump, and light colored, and is taken as a standard of quality and appearance for the budded grade of nuts.

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square openings. The nuts which drop through the openings are known as the Standard Budded grade; those which are too large to pass through the openings come out at the lower end of the grader and are known as the Fancy Budded grade. The latter grade, composed of the larger nuts, constitutes the highest priced, so-called "budded" nuts. In addition to the size requirements here described, an ideal budded nut should have a plump, sound kernel of a bright, light-straw color, and be free from mould. The shell must be of a clear, bright color, free from any discoloration.

[8] For a more complete description and history of the following varieties, as well as the more uncommon ones, see Univ. of Calif. Experiment Station Bull. No. 231, 1912, and U. S. Dept. of Agr., Bur. of Plant Indus., Bull. No. 254, 1913.

The Placentia variety has been grown with marked success throughout the coastal sections of southern California, and some of the best grafted trees in the inland valleys of the south are of this variety. The Placentia has not become popular with the walnut growers of central or northern California, because it seems to lose there some of its tendency for precocity and heavy production, and is further hampered by its production of dark-meated nuts.

EUREKA[9]

This variety was originally selected because of its supposed resistance to walnut blight, the heavy production of the parent tree, and the exceedingly high quality of the nut. The supposed resistance to blight is largely mythical.[10] The mistake was due probably to the great variation in blight occurrence during different seasons, with the possibility that, during the early years of observation of this variety, the blight may not have been normal in its prevalence or season of occurrence in the district surrounding the original tree.

The Eureka is not usually so readily propagated upon the black walnut root as some of the Santa Barbara soft-shell varieties. The trees are vigorous growers, although the growth may not be so great as that of the Placentias in the same orchard. The Eureka is later in reaching an age of profitable bearing than the Santa Barbara soft-shell varieties in southern California, and although the high quality of the Eureka nuts causes them to sell for more than the Placentia the difference averages only about 2½ cents a pound. This higher price has not made up for the lighter crops which are obtained, in most instances, during the first 10 to 15 years. Comparisons cannot be made between mature trees of these varieties, as the Eureka has been so recently introduced. In some instances the Eureka seemed to have a tendency toward biennial bearing. It is to be hoped that this variety may prove more productive in southern California as the trees become 15 to 20 years old, as the nut itself has many points to commend it, and large acreages have been planted with this variety.

The tree blooms much later than most other varieties and often escapes injury to the flowers by late spring frosts. Its harvest season

[9] The parent tree of the original Eureka tree was a Persian or Kaghazi type of walnut which grew on the old Meek estate near Hayward, California. The seedling which developed into the original tree is now a mature tree near Fullerton, California.

[10] For account of the blight occurrence in the Eureka walnut, see Fawcett and Batchelor, "An Attempt to Control Walnut Blight," Monthly Bulletin, Dept. of Agric., State of California, May-June, 1920, p. 177.

is fully three weeks later than that of seedling nuts, or of the Placentia. This is a distinct disadvantage in marketing the crop in the eastern cities in time for the holiday trade.

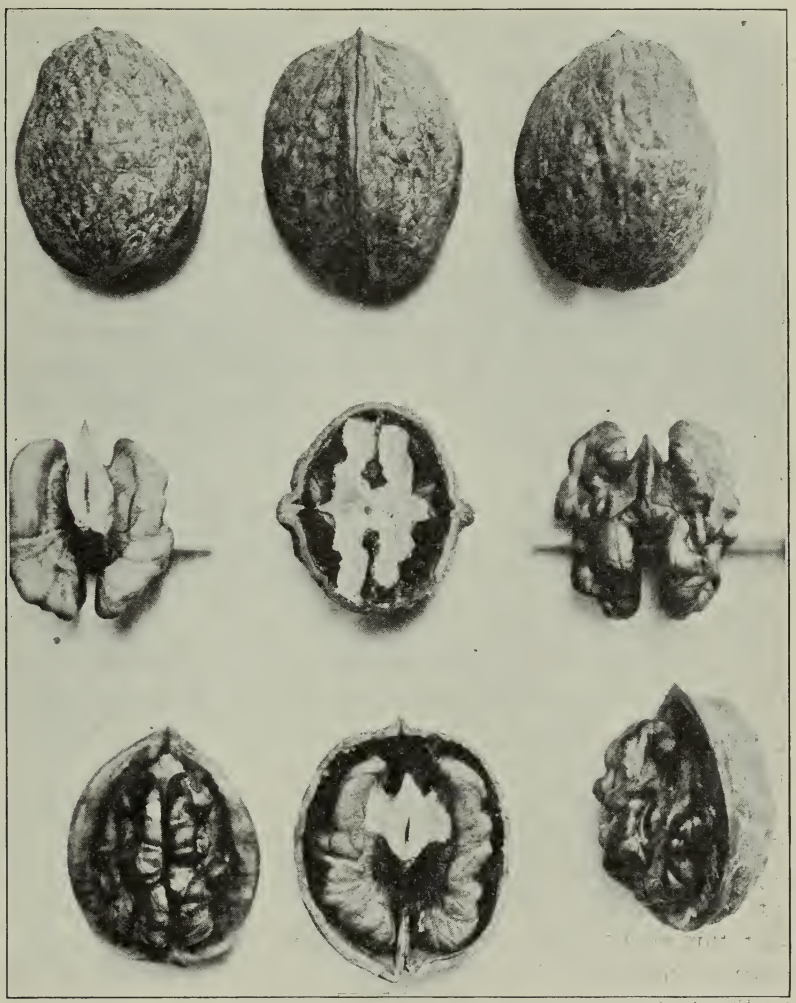


Fig. 3.—Placentia.

The Eureka variety has suffered a great deal from injury caused by being frosted during the early fall. Whether this is due to a characteristic of late ripening, or to the possibility that the Eureka has been planted in places more subject to frost than other varieties, cannot be definitely stated at this time.

The Eureka may escape with less injury from sunburn than do some varieties, as its leaves are larger and the nuts are borne in a position on the twigs which affords more natural protection than most varieties have. This does not make the Eureka entirely immune from sunburn injury, however, especially if the hot weather occurs in June or early July, when the nuts are only half-grown, and before the foliage is fully developed.

The Eureka nut is easily distinguished from any other variety grown in southern California by its pronounced elongation, rather straight parallel sides, slightly rounding to square ends, with the apex usually broader and more nearly square than the base. The color of its shell is a bright straw, of a lighter, more attractive shade than the typical soft-shell nuts. The extra heavy shell and the exceptionally and completely firm "seal" of the nut, make it a model nut for good keeping qualities, and for withstanding commercial handling. A well-grown Eureka nut is filled to its full capacity with a light, cream-colored, plump, waxy, kernel, with rather deep convolutions, possessing the very best of eating qualities. The Eureka is richer and freer from astringency than the soft-shell varieties.

This variety has made many friends in central California around Stockton and San José, and in some of the hot inland valleys of southern California, where it seems to be more promising for profitable production than the Placentia.

The kernel of the Eureka walnut will not fill out perfectly on all four quarters unless the trees are amply supplied with soil moisture. The variety has been disappointing in some of the central California districts, where the trees have not been adequately supplied with irrigation water.

On the merits of its eating quality and the attractive appearance of its kernel it might be expected to out-sell the Placentia more than 2½ cents a pound; however, this average figure of the past is the only safe guide in projecting a business undertaking. It is to be hoped that this superior nut will eventually prove to have the tree and bearing characteristics necessary to make it the leading variety in southern, and more especially, central California; the evidence at hand, however, does not justify an unqualified business confidence that such hopes will be realized.

EHRHARDT

This variety has only recently been planted commercially.[11]

Origin.—The location of the original seedling tree from which this variety sprang is apparently unknown. The tree was first selected and propagated by the late D. C. Disher, who sold fifty grafted trees to V. E. Ehrhardt, of Santa Ana, during the spring of 1906. The variety had not been given a name by Mr. Disher at that time, but the above trees were delivered as a substitute for Placentia, with Mr. Ehrhardt's sanction. Mr. Disher's only explanation and description of the trees was that they were propagated from a selected Santa Barbara soft-shell seedling tree of unusual superiority, and he further announced his intention of propagating from this tree extensively and offering it to the trade as a new variety. Unfortunately, Mr. Disher died soon after the above transaction, without disclosing the location of the original tree.

The writer's attention was first called to these grafted trees by Mr. Charles Knowlton, of Fullerton, in the spring of 1915. Since then, many observations have been made, especially to determine the amount of blight prevalent and the yields of the several seasons. The variety has attracted considerable attention locally, and is now commonly known as the "Ehrhardt."

Following is a description of the nut and the trees:

NUT

Size.—Larger than the average Santa Barbara soft-shell nut, requiring approximately 34-40 nuts to weigh a pound.

Form.—Broadly oval, base rounding, sometimes slightly pointed, apex rather blunt, suture shallow, flange rather prominent.

Surface.—Medium to smooth.

Color.—Medium light brown.

Cracking Quality.—Nuts well sealed at both ends when properly handled at harvest season; kernels readily cracked out whole.

Kernel.—Very plump and well developed, usually of a light tan color. Good market type, averaging about 50 per cent of the total weight of the nuts.

Flavor.—Mild, pleasant, and free from any decided astringent character.

[11] For a detailed description and history of all other varieties mentioned here, the reader has been referred to publications which were issued before the public appearance of the Ehrhardt. A similar account of this walnut is therefore given here.

TREE

Foliation Period.—Quite early, about same as Placentia.

Growth.—Vigorous, typical of this type of nut-tree, producing a large amount of lateral twigs.

Foliage.—Dense.

Harvest Season.—Medium to early.

Precocity.—Very early producer; apparently this is second to none. There are 38 of the original planting on Mr. Ehrhardt's property at the present time; their average yields for six years are shown in the table under productiveness.

Productiveness.—This is very heavy producing variety, as shown by the following yields of the original 38 trees on Mr. Ehrhardt's property.

10th season	(1915)	80 lbs. per tree.
11th season	(1916)	76 lbs. per tree.
12th season	(1917)	79 lbs. per tree.
13th season	(1918)	81 lbs. per tree.
14th season	(1919)	117 lbs. per tree.
15th season	(1920)	98 lbs. per tree.

The Ehrhardt walnut is of the Santa Barbara soft-shell type, closely resembling in some ways the Placentia. It is somewhat rougher, slightly larger and better "sealed." The kernel gives the impression of being plumper than that of the Placentia, because its convolutions are very shallow.

It is as yet too soon to make definite statements concerning the commercial value of this variety. It will probably succeed where the Santa Barbara soft-shell succeeds. After observing the thirty-eight trees on Mr. Ehrhardt's place for six years, it seems reasonable to expect that the Ehrhardt will some day prove its superiority to the Placentia as a heavy yielding variety. The Ehrhardt trees were nearly free from blight during 1915 and 1916, when this disease was very widespread. At no time did the writer observe as much as 5 per cent of blighted nuts on the Ehrhardt trees, while Placentia trees in the same orchard were blighted as badly as 45 per cent, and seedlings showed 65 per cent by actual count. Since 1916, the outbreaks of blight have not been severe enough to really test this character of the Ehrhardt.[12] However, whether largely resistant to blight or not,

[12] No explanation can be offered of the freedom from blight of the Ehrhardt trees during 1915 and 1916. The Placentia trees were of the same age or younger, growing in the same orchard, and across a narrow highway. The two varieties bloom at practically the same time.

its tendency to produce very heavy crops of high-grade nuts, apparently out-yielding the Placentia, makes this new variety worthy of commercial trial.

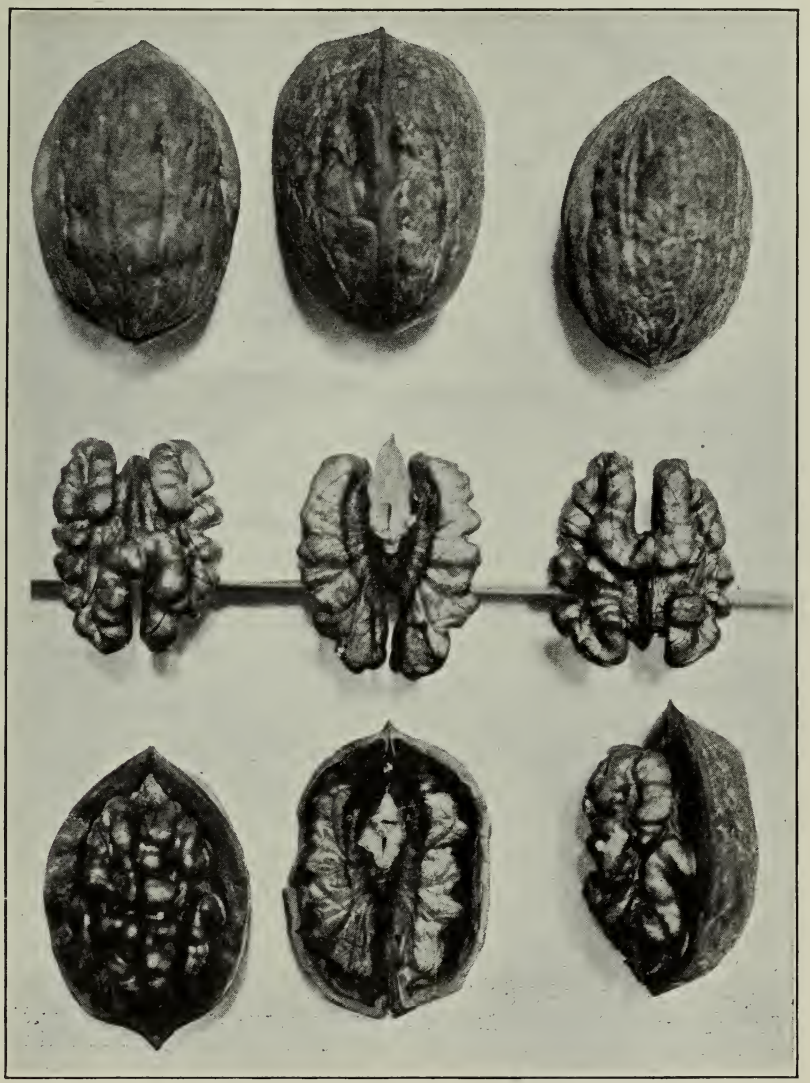


Fig. 4.—Eureka.

The Ehrhardt is readily propagated upon the black walnut root, making a tree of medium vigor which bears at an early age. The nuts are considered very promising by the wholesale trade. They easily qualify in the budded grade of walnuts.

PAYNE

Although the parent tree of this variety was discovered by G. P. Payne, near Campbell, California, in 1898, the variety has not been widely planted and only in recent years has it been propagated in any great quantity. The precocity of this variety for heavy production is probably the chief characteristic which has brought it into prominence during the past four years. It must be kept in mind, however, that walnut blight has not been prevalent to a great degree during 1918 to 1920. Moreover, the Payne is notoriously subject to blight during seasons of bad outbreaks. The recent rise in popularity of this variety may be very much altered if walnut blight prevails in the future as it did during the seasons of 1915 and 1916.

The Payne tree makes a rather slow growth, possibly because of its very heavy production as a young tree. The nuts are borne rather prominently on the outside of the trees and are thus subject to severe sunburning in the inland valleys.

The nut is oblong, rather pointed at the apex; shell of medium thickness, somewhat pitted; well sealed; kernel full, with moderate convolutions and of good quality. With the heavy production of the oldest trees growing at present, there seems to be a reduction in the size of the nut, making a high percentage of No. 2 grade. This nut has not been sold in the Fancy Budded grade, but has been sold under its varietal name. During the 1921 season it sold for less than the California Walnut Growers' Association "Fancy Budded" grades, but for one cent per pound more than the seedlings.

The greatest popularity of this variety is found perhaps in the Stockton, San José, San Fernando, and Elsinore districts. In the first mentioned district it is as popular as the Eureka. It might be suitable to interplant in a Eureka grove. Thus, the first ten years of the slow-developing productivity of the Eureka would be bridged over by this prolific and precocious variety. In the districts of the coastal counties where the blight is most regularly severe and prevalent, the Payne variety certainly cannot be recommended for permanent trees. The greatest value of this variety may prove to be its precocity and thus its value as a temporary interplanted tree among slower developing but superior varieties.

CONCORD

The Concord is one of the best tested varieties for the central portions of California, especially in Contra Costa and Napa counties, where many thousand trees are growing. In these districts, it has

proved to be a vigorous, thrifty tree, and an annual producer of medium sized crops. The Concord blooms nearly as late as the Eureka, but possibly the nuts mature a week earlier than the latter

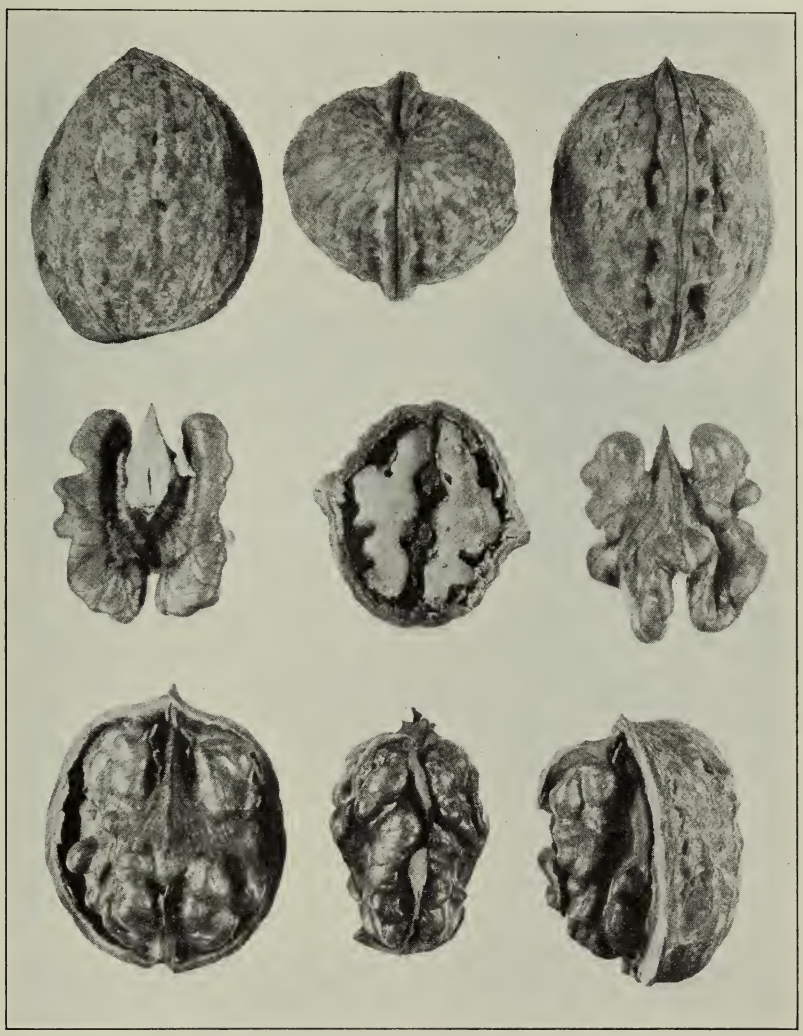


Fig. 5.—Ehrhardt.

variety. The trees are fairly precocious. The nuts are elongated and somewhat pointed at the apex; the shell is rather smooth; the nuts are poorly sealed, the kernel fairly plump, with medium to deep convolutions, only medium light-colored and of good quality. This variety is not so well received by the wholesale trade as the Placentia

or Eureka. It is doubtful if it should be planted where the two above-mentioned varieties will succeed. In southern California the Concord does not yield so well as the soft-shell varieties, so far as they have been observed by the writer. Possibly the oldest Concord trees in southern California are a group of top-grafted trees on the Pasadena sewer farm. The trunks are soft-shell seedlings, while the tops, now 10 or 12 years old, are as large as 15 to 20 year old trees. This group of Concords has produced, annually, a medium crop during the past four years. Nothing definite can be said about the blight, as it has not been severe anywhere in this orchard during the period under consideration.

FRANQUETTE

This variety has been tested longer in central California than any other. Successful commercial plantings of Franquettes occur in Sonoma, Napa, Contra Costa, Santa Clara, and Tulare counties. This variety has many adherents in these sections because of its regular bearing of moderate size crops of excellent quality. The Franquette has borne too lightly in the Stockton district to be recommended for commercial use. In southern California, the Franquette has not proved commercially successful, owing to its slow growth and light crops.

The Franquette is late in reaching a bearing age. It blooms very late, and the harvest season is too late for the most advantageous disposal of the crop for the eastern holiday trade. Owing to its late blooming it usually escapes injury by late spring frosts.

The nut is large, elongated, pointed, fairly smooth, and of a lighter, clearer and more attractive color than the soft-shell types. The shell is thin, but well sealed, and fairly well filled with a very light colored, moderately plump kernel. The eating qualities of the Franquette are unsurpassed by any variety grown in California. The high quality of this nut makes it sell for a higher price than most other varieties grown in the state, except the Eureka.

Where ample irrigation water is available, the Eureka seems to be gaining in favor more rapidly than the Franquette. In sections of rather heavy winter rainfall, where walnuts are usually grown by dry-farm methods, it is probable that the Franquette will be chosen, as the Eureka may not produce a well-filled, plump kernel under such conditions. The heavy weight of the Eureka nuts may make them preferable even in the localities where the Franquette is successfully grown, if the soil moisture conditions are favorable to the former variety.

ROOTSTOCKS[13] AND CHOICE NURSERY TREES

CHOICE OF ROOTSTOCK

The choice of rootstocks for the walnut has narrowed down during the past 20 years to a predominating preference for the northern California black walnut (*J. hindsii*). The seed is shipped commercially by several agencies from central California for this purpose. Groups of dooryard and border trees usually furnish this seed. Some nursery men in southern California have located and use seed from particularly vigorous black walnuts of this species, which have been planted locally. The seedlings from a group of such trees vary considerably, and in some instances certain trees are especially valued because of their tendency to produce uniform and vigorous seedlings. This species of black walnut will apparently withstand a more unfavorable soil condition than the seedling English walnut. Its resistance to oak-root fungus (*Armillaria mellea*) is also a valuable characteristic of this rootstock. The northern California black walnut is more vigorous as a nursery tree than the eastern black walnut, which was formerly used to some extent, only to be discarded in recent years.

The southern California black walnut (*J. Californica*) is seldom used at present, because of its tendency to sucker profusely at the crown as an orchard tree, and its susceptibility to root-rot troubles on heavy or poorly drained soils.

The paradox-hybrid walnut, which is a cross between the English and any of the black walnuts, makes a remarkably rapid growing tree. Mature trees may have a spread of over sixty feet. The vigor of this first generation hybrid has been mainly responsible for its popularity among some planters. Such trees cannot be secured in quantity, however, so that their use will always be restricted. The increased vigor of the first-generation hybrid is not carried on to following generations; in fact, the first-generation hybrid trees are usually nearly barren and their seedlings show many types of growth and vigor, making undesirable rootstocks.

The Royal-hybrid walnut is a cross between the eastern black walnut and the California black walnut. It is thought by some, that the second-generation Royal-hybrid is equal or even superior to the northern black walnut as a rootstock. There may be such hybrid strains which justify this confidence, but, as a whole, it cannot be said that such superiority has been proved. Seedlings from some of the Royal-hybrid trees produce uniformly vigorous trees, while those from

[13] For details of nursery propagation, see Univ. of Calif. Experiment Station Bull. No. 231, 1912.

others are variable to a great degree and lack vigor. Very likely the pollinating parent has much to do with this lack of consistency.

METHOD OF PROPAGATION

The English walnut is usually grafted on to the black walnut root during the early spring, using a whip graft. It can be budded,[14] however, and some nurserymen prefer this method.

REQUIREMENTS FOR GOOD NURSERY TREES

In the case of the grafted trees, the black walnut trees are grown one year in the nursery and then grafted in late winter; the grafted trees should grow from 6 to 12 feet the summer following. Such trees are trained to a whip growth and usually sell according to size, a premium being placed upon the larger trees. The pre-war price of well-grown walnut trees was from $1.00 to $1.50; during 1919–21 trees have sold as high as $3.00 each for 6 to 8-foot trees. A medium sized tree (8 to 10 feet) may be preferable to either an extremely large, or a small tree. A very large tree may be injured considerably in digging from the nursery, while a small tree may be a stunted tree with a poor root system and never make a first-class orchard tree.

STARTING THE YOUNG ORCHARD

LAYING OUT THE ORCHARD

From 12 to 27 walnut trees per acre are found in the mature orchards. General observation and the opinions of many walnut growers seem to agree that the plantings of the past have been made with the trees too close together in many instances.

If the trees are spaced 60 feet apart each way, planted on the square system, it will require 12 trees per acre; orchards planted in this manner are among the most productive in the state. When spaced 60 feet apart, the individual trees have ample room to develop fully and a large proportion of the nuts are produced on the side branches. With only 12 trees to the acre the root systems of the trees are not so crowded as in closer planting, and the trees maintain a healthy vigorous growth of new fruiting wood when they are thirty years old, or older.

[14] The question is often asked: "What is a budded walnut?" The grade of nuts sold under the name "budded" has no doubt prompted this question in many instances. A budded nut is any one of the varieties which will grade according to the standard of perfection set by the Placentia. The tree which bears such a nut has been produced by budding or grafting a bud or scion of the variety in question on a black walnut rootstock. The English, or the hard-shell, are seldom used as a rootstock at present. If budded, the work is usually done in August, using a patch or a shield bud from the current season's growth.

In the close plantings, where the trees are only 40 to 50 feet apart, the side branches are shaded most of the day, the fruit spurs on the lower branches soon die, and the crop is borne mainly in the tops of the trees. A closely planted grove is illustrated by Fig. 6. Such orchards have not maintained their productivity so well as those planted further apart. Plantings where the trees are now growing 40 or 45 feet apart can be thinned out by removing every other tree in each row so that the trees alternate, or stand opposite a space in the adjacent rows, then the remaining trees will stand approximately 57 or 63 feet apart respectively, in the rows, running diagonally across the orchard. This may be made clearer by the following diagram:

DIAGRAM I

SHOWING METHOD OF THINNING OUT TOO CLOSELY PLANTED ORCHARDS

o x o x o x o x o x o x o x
x o x o x o x o x o x o x o
o x o x o x o x o x o x o x
x o x o x o x o x o x o x o
o x o x o x o x o x o x o x
x o x o x o x o x o x o x o

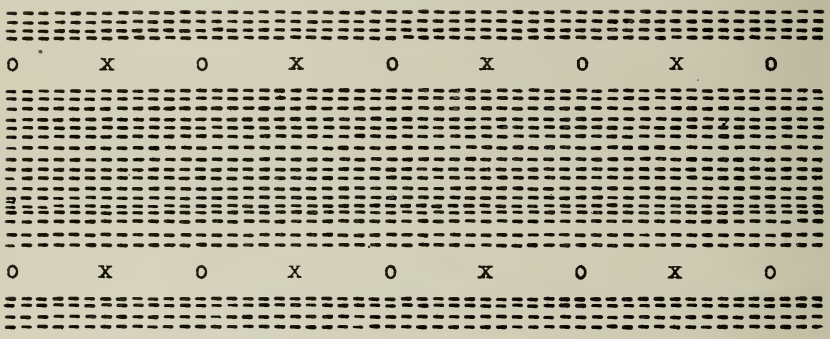
o Permanent trees to remain.
x Trees to be pulled out.

Figure 7 shows a view in an old seedling orchard after the thinning process had advanced to the stage of cutting off the tops of the condemned trees, ready for the stump puller. This paragraph concerning thinning old orchards is placed here under the general heading of *planting* with the realization that many prospective walnut planters can benefit by the experience of those who have blazed the way in this industry.

One of the most favored systems of planting at present is to plant the trees in rows 60 feet apart with a distance of 30 feet between the trees in the rows. The trees may be all of one variety, or, in localities where the varietal adaptation is in question, two varieties may be planted alternately. When planted according to this latter method, there is less hazard of planting the wrong sort, as one may have a choice between two varieties after they reach a bearing age. Such

plantings are usually thinned out when the trees are from 10 to 14 years old, according to the variety, soil, water and climatic conditions. They should not be left until they crowd badly. By this method, properly carried out, nearly twice the tonnage per acre may be expected during the first 10 or 14 years' growth as where only the permanent trees are planted. At the same time, there is practically as much room for intercrops, such as beans, during the early life of the orchard as where only 12 trees are planted per acre. The extra expense of buying and planting filler trees may be paid for by part of a year's crop, while all other extra expense due to the filler trees, such as pruning, extra water, etc., is of minor importance.

The following diagram illustrates this plan of setting out filler trees.



CARE OF TREES BEFORE PLANTING

If the trees are received from the nursery before the ground is ready for planting, they should be unpacked and heeled in, in a shady place. Water the soil around the roots thoroughly after heeling them in. If it is more practical, the trees may be held for a time under a shed with the roots packed in damp sawdust or shavings.

Just before planting, the root system should be trimmed, to cut off any mutilated portions of the tap root or lateral roots. In fact, if the ends are all cut back slightly with a sharp pruning knife, leaving a clean smooth cut, the new rootlets will start out much more readily from such a surface than from a ragged cut or a torn and bruised root.

Fig. 6.—The trees in this orchard were planted too close, being spaced 40 feet. They are producing walnuts only in the tops and will soon have to be thinned in order to obtain a satisfactory yield per acre.

Fig. 7.—A grove showing every other tree removed in each row, so that the trees alternate.

PLANTING THE YOUNG ORCHARD

Walnut trees should be planted during January and February so that the soil may thoroughly settle around the roots, and growth start with the beginning of the normal growing season, which is usually early March, in southern California. Holes should be dug deep enough to allow room for the full length of the tap root, which may be from 18 to 30 inches. The lateral roots may be 6 or 8 inches long, and the hole should be wide enough to accommodate them without cutting back except to remove mutilated portions.

In filling in the soil around the roots, it is advisable to use the top soil, tamping it thoroughly without bruising the roots. A better stand of trees may be expected, and a more prompt growth in the spring, if the young trees are thoroughly irrigated as soon as they are planted. This can be accomplished by running a single furrow along the row and cutting the water in at each basin left around the trees as the holes are filled. Irrigation at this time may not be essential from the point of view of soil moisture available, but it will be worth the pains as a means of thoroughly settling the soil around the roots to prevent them drying out. A few light rains should not mislead the planter and cause him to omit this first irrigation at planting.

TRAINING YOUNG TREES

If walnut trees are allowed to grow without any pruning, they will usually take their natural form of a medium tall, upright, pyramidal tree, with a pronounced central leader. At the time of planting, walnut trees are usually headed back 5 or 6 feet from the ground, and the upper lateral bud will frequently make an upright limb which will take the place of the removed top and continue the leader form of tree. If this central branch is pruned off, however, the lower lateral branches will form a more open vase-shaped tree. These lower lateral branches thus once started, take all the strength of the tree and another leader seldom becomes established. Figure 8 shows an eight-year-old tree growing as a leader type.

Both the central leader and the open vase types of trees have their advocates. The advantage of the leader type of tree is primarily in the greater strength of the framework, there being many more lateral limbs distributed along a greater space on the main trunk than with the vase-shaped type, and thus less likelihood of breaking, compared with the latter type. In the case of the vase-shaped type the few branches originate at nearly the same point on the main trunk and

this centralizes the strain of supporting the crop. In the case of the vase-shaped trees, it is not unusual for one-quarter or one-half of the tree to break off and, in extreme cases, there may be a split down the middle and the tree be entirely destroyed.

Fig. 8.—Central leader type of walnut tree. This type has a strong framework of branches, and plenty of fruiting wood.

Figures 9 and 10 show walnut trees eleven years old, which were trained to the open vase shape. It was necessary to have from 15 to 20 per cent of the trees in this grove braced by the time they reached an age of profitable bearing. Eventually the owner will have to go to the expense of bracing nearly every tree in the grove. The examples here illustrated may be considered extreme because the lateral limbs originate at so nearly the same point.

The advocates of the open vase-shape tree claim that a greater area of fruiting wood is exposed to the sun in this form of tree than in the leader type. This point is hard to verify, and the greater hazards of breaking may offset any such supposed advantage.

After one has decided upon the type or ideal toward which the young trees are to be trained, the pruning operations should be consistent in following this initial decision. In training the young walnut tree, very little pruning is necessary. Walnut trees as they are received from the nursery are usually one-year-old whips. If vigorous 8 to 12-foot trees are planted they are usually cut back to within 5 or 6 feet of the ground.

Trees thus planted will frequently start to grow first from the lower buds within 12 to 24 inches of the ground, or will send out shoots along their entire length. This growth should be rubbed off by going over the trees frequently during the early summer, keeping all buds off which occur within 4 or 5 feet from the ground, according to the form of tree to be grown, and their height at planting. If the lower lateral buds have made a growth of 8 to 10 inches it is advisable to "pinch off" the growing tips which will have the effect of forcing the growth of the upper shoots, while the growth of the lower shoots is restricted. The smaller lower shoots thus produce shade and nourishment for the trunk. If the lower dormant buds are rubbed off at planting, all the growth will take place in the upper buds without further attention. If, on the contrary, these lower buds are allowed to grow, the buds on the upper 24 inches of the tree may remain dormant; in fact, in many instances the upper portion of the tree dies back 12 to 24 inches. With the lower buds suppressed, however, the upper buds are forced into growth and the framework of the tree is started in the upper 24 inches of the trunk.[15] This is illustrated by Fig. 11.

[15] A few planters advocate cutting the young tree back to within 12 to 16 inches of the ground. This method forces into growth the latent buds near the ground; one of these is selected to make the tree, and all others are rubbed off. The selected shoot must be staked and tied to a 2″ × 2″ stake, 5 to 6 feet tall, otherwise the supple growth will be whipped around and bent over by the winds. It is claimed that this method gives a better stand of trees, and less liability of sunburn injury on the trunk. The tops thus cut back are relatively surer to balance up with the root systems injured by digging. It may well be doubted if the extra expense in staking and in the care necessary to grow a tree in this manner will repay for the assurance of the growth of a larger percentage of the transplanted trees. Good, plump nursery trees, if handled properly, should transplant very readily and make nearly a 100 per cent stand of trees without resorting to this severe cutting. If they are thoroughly whitewashed, or use is made of tree protectors, sunburning need not be feared. It may be advisable, however, if one is using inferior trees or such as have dried out in transit, to cut them back within 16 inches of the ground.

Whether the ideal selected is the leader type or the open vase shape, it is desirable to select the lateral branches for the framework of the tree, spaced as far apart as practical when the young trees are pruned at the end of the first year's growth.

Fig. 9.—Result of heading low, starting all the branches from one point. This could have been prevented when the tree was young by spacing the branches through a greater distance on the trunk of the tree.

With the vase type this perpendicular spacing throughout 18 to 24 inches will give greater strength to the framework than grouping the

branches at more nearly one point of origin. The lateral branches to be left for the framework of the tree may be 3 to 5 in number, as evenly spaced as possible as they radiate outward from the trunk.

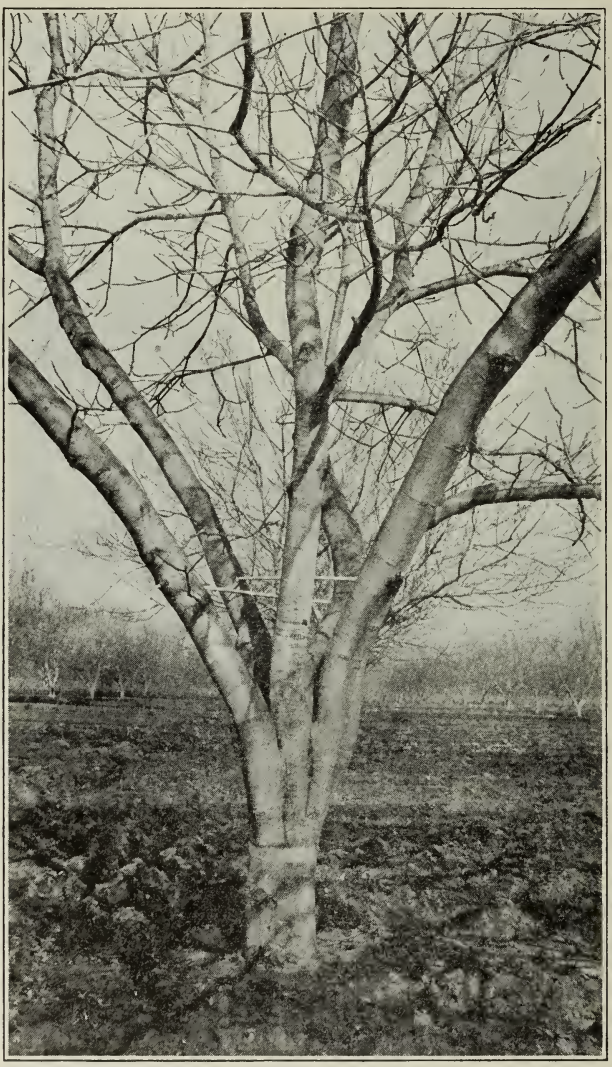


Fig. 10.—Method of bracing open vase type of tree to prevent splitting.

The upper or second bud from the top of the original tree will usually produce a branch which grows in a nearly upright position; this, of course, should be "pinched back" during the early summer or cut

out during the dormant season, in forming the framework of an open vase-shaped tree. Figure 12 illustrates an example of this type of tree.

In the case of the leader type it is essential to space the laterals far apart and not leave too many; otherwise the leader, or central shaft, will be "choked" out, as illustrated by Fig. 13. Only two or three of the laterals should be left in addition to the central leader at the end of the first year, as other lateral branches will grow out during the following years from the central leader; thus the shape of the trees is formed during the first two or three years' growth. The branches which are left on the tree are not cut back in common practice and by all means the leader should not be cut back. Figure 8 shows a desirable shape for a tree of this type.

Some of the most desirable types of trees judging from the viewpoint of strength of framework and area of bearing surface, are a sort of modification of both the leader and the vase-shaped type. Figure 14 illustrates such a tree; there is a pronounced leader through 4 or 5 feet of the main frame of the tree which finally divides up into a strong, compact, spreading type of tree. This type can be trained by maintaining the leader type through the first four years and then during the dormant season, pruning back the leader to a strong lateral branch 9 or 10 feet from the ground. The tree shown in the illustration might well serve as a model, or ideal, in training young walnut trees.

VALUE OF ORCHARDS AND LANDS

The valuation of walnut orchards and lands suitable for walnut production varies considerably in the different localities and even in the same districts. Such factors as suitability of the soil, water rights, frost conditions, and proximity to transportation and civic centers are reflected in the appraised valuation of walnut properties. The value of established groves may be greatly influenced by the variety of nut, rootstock, planting arrangement, etc. The average or the most general valuations are all that can be presented here.

Replies to questionnaires sent out by the California Walnut Growers' Association in 1919 and again in 1921, indicated that mature bearing orchards are valued at about $1400 per acre, while the young non-bearing properties are valued at approximately $900 per acre. The following table shows the exact average valuation and the number of properties considered.

TABLE IV

AVERAGE VALUATION OF WALNUT GROVES
(Including water rights)

Year observations were made	Valuation		Number of properties represented
	Bearing	Non-bearing	
1919*	$1299.02	$995.00	922
1921†	$1477.05	$826.65	231

Land suitable to walnut culture, plus adequate water rights, may be purchased at from $600 to $1000 per acre in the proved walnut-growing sections of southern California. Such land may have a rather fixed value for the production of beans, beets, or even citrus fruits; thus its potential value for walnut production is only one factor which determines its appraisement.

In the central or northern portion of the State, where the walnut industry is not so extensively developed as in the south, land which is likely to prove suitable for walnut culture may be purchased for $200 to $300 per acre. This may not include a water right in any established irrigation system, but such lands occur in areas where good wells are known to exist.

CULTURE

SOIL MANAGEMENT

There is no one best way to cultivate all walnut groves. The methods of performing the various operations of stirring the soil, such as plowing, discing, and harrowing, vary widely in different walnut groves. These different methods may give equally good results in their respective groves, when measured by profitable crop production. A practice which leaves one soil in first-class condition may be very poor practice on another soil of a different type. Most walnut trees are deep-rooted and it seems quite apparent in many cases that the character of surface soil cultivation is of only minor importance to the welfare of the tree, except as this cultivation affects the conservation and use of soil moisture by the tree. There are many door-yard and roadside trees which produce heavy crops and yet the soil around them may not be stirred from one year's end to another. It does not follow from this, however, that a walnut grove should not

* "The California Walnut," p. 15, 1919. Published by The California Walnut Growers' Association.

† Brief of Facts Relating to the American Walnut Industry, p. 23, 1921. Published by the Walnut Protective League.

be plowed or cultivated. There are frequently many conditions surrounding roadside and dooryard trees which are favorable to the presence of an abundance of soil moisture, which cannot be duplicated under orchard conditions. Isolated trees have the advantages of better exposure to sunlight and a far greater range for root development and available soil moisture than trees planted in orchard form.

a *b* *c*

Fig. 11.—Walnut trees when planted are usually cut back to within 5 or 6 feet of the ground.

(*a*) If they are not trained they will frequently send out shoots along their entire length during the early summer.

(*b*) Frequently if the lower buds within two feet of the ground are allowed to grow, the upper 24 inches of the trees may remain dormant.

(*c*) If the lower buds are suppressed the upper ones are forced into growth and the framework of the tree is started in the upper 24 inches of the trunk.

The majority of walnut groves are plowed once a year, usually in the very early spring. A disc, springtooth or spiketooth harrow is then used to put the land into good physical condition. The clean cultivation during the summer months is done in relation to the irrigation practice and the conservation of soil moisture.

The practice of plowing the groves once a year seems essential to most of the soil types found in the walnut districts of California. The relation of such plowing to the penetration of the rains into the subsoils and the application of irrigation water alone justifies the operation. Putting 6 to 10 inches of the surface soil into a friable, mellow condition every year makes it practical to use deep irrigation furrows and thus to insure deep penetration and a more complete use of the irrigation water applied the following season. An annual plowing prevents the tree roots from becoming permanently established in the surface six inches of soil, and thus becoming subject to the great variations of soil moisture content which occur there during the summer months.

If the land is plowed in the fall and left rough, the rains may be expected to penetrate deeper into the subsoil because of the lessened run-off. This object is accomplished best, in some instances, if the plowing is done at right angles to the grade of the land. Where a winter cover crop is grown, fall plowing may be impractical because of the necessity of planting the cover crop early, either just before the harvest, or immediately after. When winter cover crops are not grown, the practice of fall plowing has much to commend it. A medium to light irrigation may well precede the fall plowing, and the land left rough without further cultivation until the early spring.

Late spring plowing is objected to by some walnut growers as they believe the cutting of the feeder roots by such plowing to be especially harmful when the tops are just starting to grow, during late March and the month of April. The instances which are frequently cited to illustrate the poor crop conditions following late spring plowing, are not readily diagnosed. It usually seems that there may be other more important factors conducive to poor crops, accompanying the late plowing. The dry soil condition which is so frequently correlated with late plowing, may in itself be more truly responsible for the poor crops than the mere season of plowing. Many orchards which are plowed late are cover-cropped or heavily covered with volunteer growth of barley, oats, native annual plants, etc. In most seasons, and in most walnut districts, the presence in late March or early April of a sown cover crop or a volunteer crop, may be taken as a safe indication that the soil moisture is largely depleted, unless the

land has been thoroughly irrigated once or twice during the growth of the crop. The orchard in which a volunteer crop is allowed to grow is most likely to be neglected in regard to winter irrigation. Many such orchards are plowed in the spring when the annual plants have actually wilted for lack of moisture, or after recent rains have revived them by moistening the soil only to the depth of the plow

Fig. 12.—A typical open-vase type of tree.

furrow. The subsoil from the second to the eighth foot, in groves thus managed, may be nearly dust dry at this season when the trees are commencing to leaf out.

The amount of water required to produce a cover crop is often underestimated by the walnut grower. This is especially true when the crop is produced during the rainy season and makes a satisfactory growth without irrigation. This matter is more fully treated under the heading *"Cover Crops."* Many such instances of the above have

been noted, when an examination of the subsoils has shown a dryness[16] hardly credible. The fact that the orchard was being plowed at the time the observation was made, and a few feeder roots were being cut in the late spring, has seemed to some observers as unimportant, compared with the extremely unfavorable soil moisture conditions existing at the commencement of the growing season for the trees. It seems reasonably safe to assert that the chief factor contributing to poor crops in many late plowed orchards is the dry soil condition during the winter and early spring, and the late plowing which may be associated with this dryness is in no great degree responsible. Late plowing may be accompanied by ideal soil moisture conditions as noted later, in which case the crops may not suffer.

Judging the question of late spring plowing from another angle, there are many first-class, heavy producing orchards which are annually spring-plowed in April, when the leaves are coming out on the trees. Some of these orchards are located on the lowlands subject to winter floods, where it is necessary to cover crop the land to prevent erosion and where this threat of flood damage is not past until April. Orchards in these districts are seldom or never plowed until late, yet many of them produce approximately 2000 pounds per acre. Such plantings are usually well irrigated during the spring or late winter months, however, either by regular irrigation methods or by the passage of flood waters over the lands.

This discussion should not be taken as an encouragement to late spring plowing, as there are points in favor of plowing early and it seems to be the practice most usually recommended by successful walnut growers. This discussion is offered mainly to encourage growers to feel that they may maintain a first-class walnut grove, even though for any reason they are obliged to plow late, providing other factors, chiefly soil moisture conditions, are favorable to the early spring growth of the tree and nuts during March and April when such plowing is frequently done.

COVER CROPPING

The practice of cover cropping walnut groves prevails in probably somewhat less than 50 per cent of the total area of bearing groves.

[16] Walnut groves have been examined by the writer in which the soil below the penetration of winter rains contained only hygroscopic moisture. Walnut trees commonly reduce the soil moisture to this point during the fall months. A winter rainfall of 8 to 12 inches may not percolate below the second or third foot of soil if there is a cover crop or weed crop growing on the land. If the rains come in small amounts distributed over 5 or 6 months, as frequently occurs, their shallow percolation is more pronounced than when large volumes fall at a time.

Many groves which are not sown to cover crops produce a volunteer growth of various annual plants, such as bur clover, lupins, wild oats, and alfilaria, during the rainy season.

There is very little or no definite information concerning the subject of the effect of cover crops on walnut trees.[17]

Though we have no definite field trials to inform us concerning the effects of cover crops in walnut groves, a discussion of some of the factors to be considered may be useful. Possibly the primary factor is the problem of supplying sufficient irrigation water for the walnut trees and the cover crop combined. While it is true that walnut trees do not draw very heavily upon the soil moisture during the winter months, yet it is highly important to have the water content of the soil somewhere near optimum during the entire winter. It is a mistake to allow a winter cover crop to deplete the soil of its necessary moisture. There should be no misconception about the saving of soil moisture because of the shade of the cover crop. This shade and thus possible conservation of moisture in the few surface inches of soil, is hardly worthy of mention, compared with the soil moisture necessary to produce the cover crop itself.

The actual water required to produce a fair crop of the several plants commonly used as cover crops in California, has never been carefully studied, so far as known to the writer. A good general idea, however, of the water requirements of such crops can be obtained from both the controlled experiments with related plants, and the experiences of farmers.

In studying the water requirements of certain plants, Briggs and Shantz[18] found that different plants require different amounts of water to produce equal quantities of dry matter.[19]

The average requirement of alfalfa, field peas, and *melilotus alba* was 803 pounds, which is more than is needed by common grains.

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[17] The beneficial effects of plowing under green manure crops, as measured by the crops of annual plants which are later grown on the same ground, cannot be used as a safe guide in theorizing on the effects of this practice on walnut trees. In the case of annuals, there is no competition between the cover crop and the primary crop. Even with annuals, much of the benefits ascribed to the cover crop may have been due to crop rotation, as has been shown by various experiments which were so laid out as to measure this latter factor. Again, the root zone of many of the annual crops which have been used to indicate the effect of cover crops upon the productivity of the soil, corresponds more closely to the root zone of the cover crops than to that of the very deep-rooted walnut trees.

[18] The Water Requirement of Plants, U. S. Dept. of Agric., Bur. of Plant Indus., Bull. No. 284, 1913, p. 47.

[19] Dry matter is that portion of the plant which remains after all the water has been evaporated off by a temperature slightly above the boiling point of water.

TABLE V

WATER REQUIREMENTS, MEASUREMENTS OF CROPS AT AKRON, COLORADO

Crop	Variety	Water requirement (lbs.)
Alfalfa	Grimm	1068
Field peas	Canada	800
Sweet clover	(*M. alba*)	709
Average of three legumes		803

In the absence of any more information, we can use these results to estimate the approximate water requirements of the cover crops used in walnut groves.

Using this water requirement of 803 pounds of water as a guide, and a yield of 13 tons per acre as an average yield,[20] with 20 per cent dry matter, the example works out as follows:

5200 (lbs. of dry matter) $\times$ 803 (lbs. of water required per lb. of dry matter) = 4,175,600 (lbs. of water per acre) = 18.47 acre inches per acre of cover crop.

This figure of 18.47 inches is based upon control experiments where the crops were grown in cans and the surface evaporation from the soil was practically eliminated, whereas under orchard conditions there is considerable loss from surface evaporation while the young cover crop is becoming established during the early fall months. This figure is, therefore, probably too low for orchard conditions.

Turning now to a practical example: A cover crop of yellow sweet clover (*M. indica*) was grown in a one-year-old walnut grove on the Citrus Experiment Station grounds during the winter of 1920–21. The land was cropped to barley during the spring of 1920, and therefore contained practically no soil moisture available for the growth of a cover crop in the fall of the same year. The cover crop was planted in September, 1920, and plowed under in April, 1921, when it was just past full bloom. The clover growth contained some volunteer barley, so that it closely corresponded to the cover crops in the flood districts, where barley and clover are sown together. From the date of planting until the middle of March, 15.8 acre inches of irrigation water per acre had been applied to this crop. At this time the clover was just starting into bloom and the land was so dry that it could not be plowed with a mould-board plow until after it was irrigated. It was then irrigated with 7 acre inches per acre. By April 11

[20] W. M. Mertz, Green Manure Crops in Southern California, Univ. of Calif., Agric. Exp. Sta., Bull. No. 292, 1918, p. 10.

the land was again too dry to plow, and in addition to the irrigation water previously given, 7.2 inches of rain had fallen during the growth of the cover crop, making a total of 30.0 acre inches per acre which had been used by the small walnut trees and by this mixed cover crop of sweet clover and barley of maximum tonnage growing to maturity.[21]

Fig. 13.—The central leader in this tree has been starved out by the lateral branches, all starting out at nearly the same place and cutting off the food supply from the central trunk.

[21] At this time the land received an additional 7 acre inches per acre and was then plowed as soon as practicable; the last 7 inches should not be charged to the cover crop, as it was largely conserved in the soil by prompt plowing, leaving the soil in a good condition for the young trees and the planting of a summer intercrop of beans.

If the crop had been plowed just as the clover came into bloom following promptly the March irrigation[22] there would have been 15.8 acre inches per acre irrigation water and 7.2 inches of rain, making 23 inches as a total used by the crop up to this period in its growth, and leaving the soil quite as dry as it was the fall before.[23] The stage of development of the crop at this time, just beginning to bloom, would have been the ideal condition for plowing under. The tonnage was nearly at its maximum, and the green succulent condition of the stalks of both the clover and the barley would have probably assured a more rapid disintegration after plowing than turning it under in April, when the flowering season was practically past.

From the two examples cited, it seems probable that the growth of a legume cover crop in a walnut grove should be expected to require from 20 to 24 acre inches per acre of irrigation water, aside from the needs of the trees. The winter rains alone are frequently no more than sufficient to meet the requirements of the trees under clean cultural conditions. In practice this will mean from 3 to 4 heavy irrigations during the winter and early spring, in localities receiving only 10 to 15 inches of winter rainfall. (See "Irrigation.") It is sufficient here to remind the reader again that there should be ample water available to grow the winter cover crop, and that following the plowing in of the crop, the walnut trees should be given a thorough irrigation at the commencement of their early spring growth. If the requirements of the cover crop alone are considered, at the time of plowing the subsoil may be entirely too dry to promote an early vigorous growth of the trees and nuts, even though the soil is moist enough to plow with a mould-board plow.

One of the benefits derived from the use of cover crops in walnut groves has been the improvement of the physical condition of the heavy soils as a result of the incorporation of large amounts of organic matter. The experiences of many observing farmers seem to agree that the clay loams are made more friable and the irrigation water penetrates them much more readily when cover cropping is practiced. The latter point, with reference to the deeper penetration of the irrigation water, may alone justify the use of cover crops on certain soils.

The legume cover crops most commonly grown in walnut groves during the winter months are bur clover, yellow sweet clover (*Melilotus indica*), purple vetch, and horse beans.

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[22] It was too dry to plow before this irrigation, as noted.

[23] The crop wilted badly before the March irrigation and the soil was judged to be between the wilting point and the hygroscopic point.

The seed may be drilled in, or sown broadcast, and then "brushed in" or harrowed lightly with a spike-tooth harrow. The amount of seed required per acre is as follows:

Melilotus indica and bur clover	20– 30 lbs. per acre
Vetch	70– 80 lbs. per acre
Horse beans	100–200 lbs. per acre

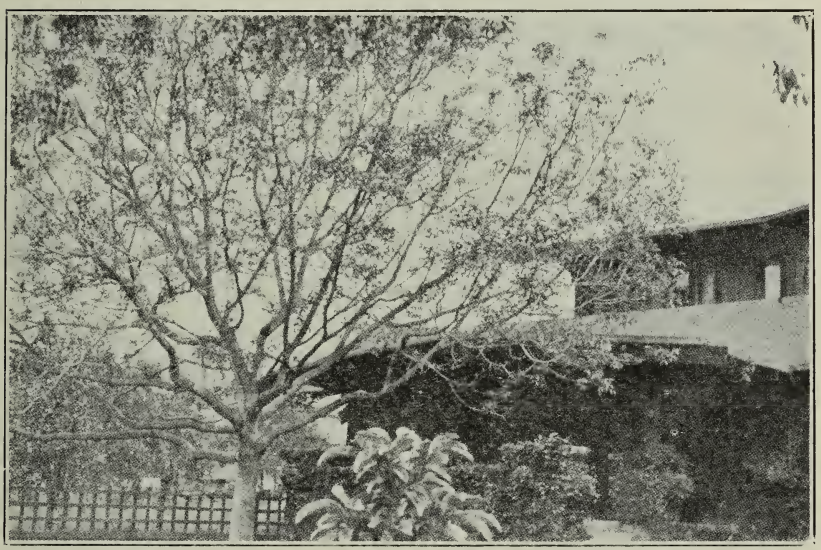


Fig. 14.—One of the most desirable types of walnut tree, combining the good points of both the leader and vase shape types.

It is essential to plant the cover crop as early in the fall as possible after harvesting the nuts, in order that it may make a good start before the cold weather commences, and thus make sufficient tonnage by the middle of March to be worth plowing under. The cover crop grows successfully, sometimes, if sown at the time the land is leveled off, preceding harvest, and the furrowing out and irrigating of the land postponed until the harvesting operations are over.

Figure 15 shows a good crop of yellow sweet clover (*M. indica*) ready to turn under in late March, while Fig. 16 shows a similar cover crop being plowed deeply after first laying the clover down with a drag. Cover crops are occasionally disced under, as shown by Fig. 17. This is not so desirable as deep plowing, because it does not incorporate the organic matter in the soil mass so closely to the tree roots. A cover crop disced under improves the physical condition of the surface soil, but it does not supplement the plant food of the soil so much as though it were plowed under.

IRRIGATION

Before discussing the irrigation of any crop, it is well to understand the extent and distribution of the root system of the crop in question. It is a commonly held opinion that walnut trees are very deep-rooted when grown on the majority of the orchard soils of southern California. There are exceptions to this general rule, but in the deep friable soils of the typical walnut sections the problem usually is not how deep do the roots go but where do they stop? In treating the matter of irrigation, the following discussion may be taken to apply to the volume of soil included in the first eight feet from the

Fig. 15.—A cover crop of yellow sweet clover (*M. indica*) ready to plow under in late March.

surface of the ground. The discussion is confined to this depth of eight feet, not because it is judged that this is necessarily the absolute limitation of the root system, but because observations have shown: first, that the root-feeding area in many groves extends to at least this depth; second, that first-class crops can be grown when only the first eight feet of soil are considered; and third, if more of the walnut growers observed and frequently examined this volume of soil, they might be able to improve their irrigation practice.

From early spring until harvest, it is essential to have adequate soil moisture available throughout the root zone, if a good tonnage of well-filled, heavy-shelled, well-sealed nuts is to be produced.

In discussing the practical use of irrigation water in producing walnuts, perhaps the subject can be most clearly presented if the water

requirements of the crop are considered from the beginning of the growing season in the spring, through the summer and harvest seasons, and on to the following spring.

Fig. 16.—Method of turning under cover crop by means of a tractor and a mould-board plow, after the cover crop has been laid down with a drag.

Unlike most other fruit crops, the walnut is grown for the seed of the plant instead of for any edible, fleshy portion which surrounds the seed. Experience in growing stone fruits, such as peaches, shows

that the size of the fruit may be greatly influenced by irrigation water applied late in the seasonal growth of the fruit, long after the pit has hardened. This late increase in the size of the fruit is caused by the increased thickness of the fleshy or edible portion of the fruit, without any increase in the size of the pit itself. The growth of the walnut compares with the growth of the pits of the stone fruits, all of which reach their full size long before harvest and before the shell is fully hardened. The walnut shells of most of the varieties begin to harden about the middle or last of June. Therefore any cultural or irrigation practice which is intended to affect the size of the nut must take place before that time.

Fig. 17.—Discing a cover crop under improves the physical condition of the surface soil, but it is probably not so advisable as plowing it under deeply, thus bringing it in closer contact with the surface roots of the trees.

The effect of early irrigation of walnut trees upon the size of the nuts was shown on the experimental plots in Hemet, where the Experiment Station and the California Walnut Growers' Association Field Department have been investigating the causes of die-back of walnut trees. In these trials, Plot A received 5.7 acre inches per acre more winter irrigation than Plot D. They were otherwise handled the same. In both cases, summer irrigation was commenced in the middle of June. The abundance of early soil moisture from the winter irrigation in Plot A produced a quick growth of sizable nuts, while the deficient early moisture in Plot D prevented the nuts from developing to normal size. The average size of a sample of the nuts from Plot A was 23 per cent larger, 11 per cent heavier, and they contained 27

per cent more edible kernels by weight, than the average of Plot D. The curves showing the volume measurement of the nuts from the respective plots, expressed in cubic centimeters, is shown in Fig. 18.

The application of winter irrigations in the southern counties as a preventive of winter injury to the trees will be more fully developed later in this section. This winter irrigation serves also to supply needed early spring moisture for the growth of the trees. Aside from the small amount of moisture transpired by the dormant trees and lost through the surface evaporation of the soil, the big bulk of the

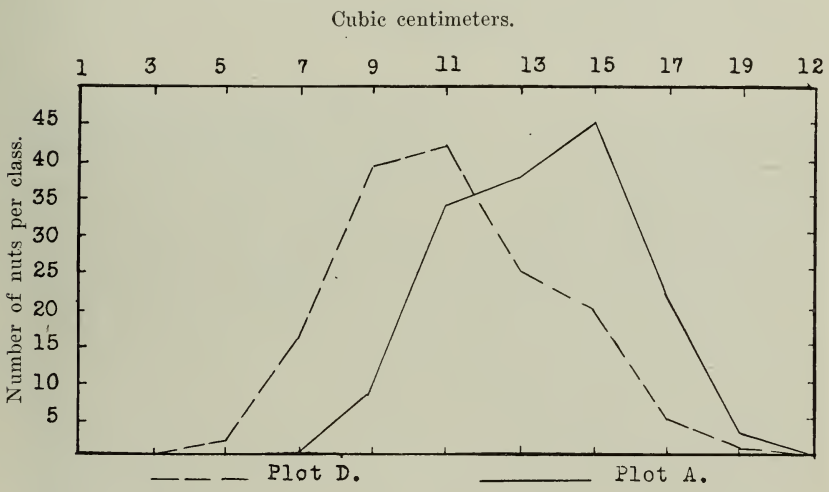


Fig. 18.—Showing the variation in size of 150 nuts each, from Plot D and Plot A (Hemet). The latter was winter irrigated 5.7 acre inches per acre more than the former.

winter irrigation water is available for the trees' use in the spring, providing it is not largely used by cover crops or weeds before the trees begin to grow. During seasons of normal rainfall this irrigation may not be needed in the coastal districts from Saticoy northward to Santa Rosa, but during seasons of light rainfall, especially in the inland districts, it will increase the percentage of No. 1 nuts in most years. A grove being thoroughly winter irrigated is shown in Figs. 19 and 21. (The illustrations are presented primarily to show different methods of applying water.)

The relation of the winter rainfall and of the consequent early spring soil moisture to the grade of the walnut crop the following season, is shown in Fig. 20.

The curves are projected on a percentage basis. The base line marked 100 in the left-hand margin may be taken to represent the average of the normal rainfall of the following stations: Los Angeles, Santa Barbara, Pomona, and Tustin. At the same time, it represents the percentage of No. 1 nuts sold by the California Walnut Growers' Association in the total volume handled during the six years noted. The dotted line shows the fluctuation of the percentage of seasonal (July to June) rainfall, ending June 30, for the respective years indicated on the bottom margin. The solid line represents the fluctuation of the percentage of No. 1 nuts handled by the same Association during the respective years, expressed as a per cent of the grade of No. 1 nuts for the total six years' crop.

Fig. 19.—If the water will move into the soil readily the use of deep furrows and the wetting of as little of the surface soil as possible will reduce the moisture loss by evaporation to a minimum.

Although the curves may not be considered parallel, they do tend to move in the same direction, except during the year 1917–18. There are many factors besides *total* rainfall which operate to affect the soil moisture available for tree and crop growth during the early spring. Among these are distribution, amount per storm, weather conditions between storms, and season of rainfall, together with the demands upon the moisture by cover crops in many cases. These may all bear more or less upon the percolation of the water into the soil and thus, finally, the amount available to the walnut tree. Again,

many walnut growers practice winter irrigation. In such cases, the volume of rain may not be a limiting factor. It is hardly to be expected, then, that the lines would be parallel during the entire period; the fact that they tend in the same direction the majority of the seasons represented is unmistakable. The fact that the lines cross between 1917 and 1918 may be due to the especial effectiveness of the small volume of rain in 1918 in percolating deeply into the soil. During the 1917–18 rainy season, the rains came late and extended over a short period, percolating to practically twice the depth in the

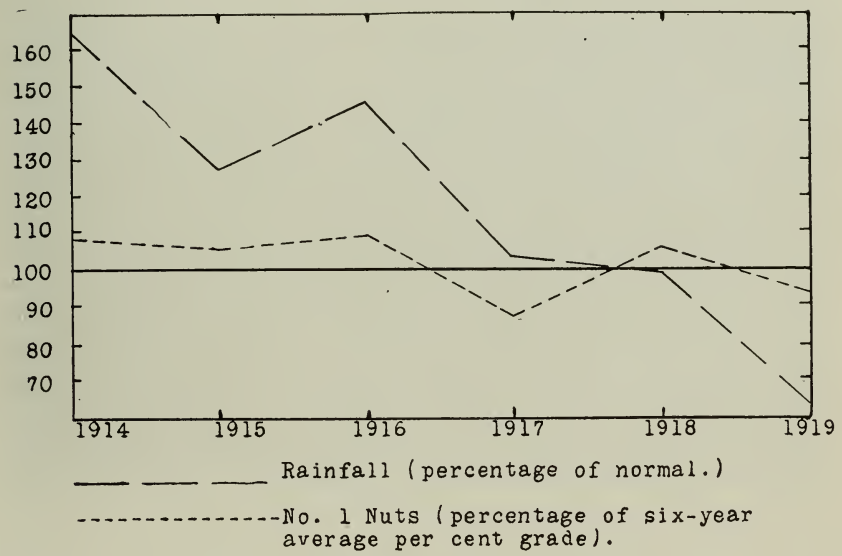


Fig. 20.—Expressed in percentages.

same soil as the 1918–19 rains. During 1918–19 the periods between rains were characterized by northerly winds and low humidity, making the rains much less effective than in the previous year. The trees may have made use of nearly twice as much natural moisture during the season following the 1918 rains as during 1919, owing to its distribution over a shorter season during the former year.

The chief thing that may be learned from this is the value of soil moisture in the early spring in producing large nuts. If this is a correct analysis of the facts presented, the practice of winter irrigation of walnut groves, which is followed to a great degree in some districts, should become a universal practice during winters of scanty rainfall.

If the winter rains plus the winter irrigation do not percolate to a depth of eight feet during the winter and late spring, it is advisable to apply the first spring irrigation sometime in April. At this season of the year the trees are leafed out and the young nuts should be rapidly increasing in size. Filling the subsoil with moisture at this season makes a reservoir for the tree roots to draw upon during the early part of the summer, while the nuts are reaching their full size.

The soil moisture due to early spring irrigation, winter rains, and winter irrigation, should be supplemented by water applied in midsummer to promote the growth of well-filled nuts with plump kernels. This may require three applications of water in June, July and August, respectively; or possibly only the first and last month mentioned, according to the type of soil and the climatic conditions. The light sandy soils will require more frequent irrigation than the heavier soils, while the walnut groves in the hot inland valleys will require more water than those on the coast, which are frequently bathed in heavy fogs and where the daily temperature is relatively low. Detailed directions for the irrigation of walnut groves cannot be presented in a general treatment of an industry which is found under such widely divergent conditions. Emphasis should be laid, however, upon the need of a continuous supply of soil moisture from the time the tree leafs out in the spring, up to and including the beginning of the harvest period. Just as the early spring moisture is essential to the production of large nuts, and the midsummer water to the full development of the kernels, ample soil moisture in early September is necessary to promote the normal development of the nut to the point where the husk cracks open and the nut drops free to the ground, leaving the husks temporarily attached to the twigs. The absence of sufficient water during the final development of the crop is almost invariably associated with the sticking of the husks to the nuts, sunburning, and a consequent high percentage of cull nuts. The shells of the nuts which crack out of the husks naturally, are mostly bright amber color and free from stains, while those to which the husk adheres are often stained, and may even be classified as culls, if the stain is too deep to be obliterated by the bleaching at the packing house. The cracking of the hulls when plenty of late summer water is applied is of the same nature as the splitting of prunes when the trees are watered as the crop is ripening.

It should therefore be the aim of the walnut grower to keep all the soil from the surface to a depth of eight feet well supplied with moisture from early spring until early fall.

It is a common observation of practical walnut growers that it is more difficult to obtain deep percolation of the irrigation waters in midsummer than in spring. This condition may be largely due to the fact that subsoils are allowed to become too dry before irrigation in midsummer. This excessively dry soil resists the entrance of moisture to a much greater degree than does a soil which is moderately damp at the time irrigation water is applied. This phenomenon of the movement of soil moisture into soils of different moisture content has been observed many times, both in the laboratory and the field.

Fig. 21.—This system of the dike and check furrow irrigation is used to prevent "run off" and obtain a deep moisture penetration.

Field observations on plots D and E of the Hemet irrigation experiment harmonize with laboratory studies which have been made of this subject. The sandy loam subsoil (fourth to seventh foot, inclusive) of D was extremely dry (practically the hygroscopic point) as early in the season as May 1, while the same volume of subsoil of plot E reached only a dryness which might be considered in harmony with good irrigation practice (somewhat above the point where most annual plants would wilt) by the first of June. The plots are adjacent to each other and were both irrigated in the same manner and given the same amount of water during June, namely, 4.2 acre inches per acre. The average penetration of the same amount of irrigation water applied on these two plots was as follows: D, 53 inches; E, 84 inches. Figure 21 illustrates an orchard being irrigated by the dike and check-furrow system. This prevents "run-off" when a large volume of water is used and secures a deep moisture penetration.

The lesson which may be learned from the above or similar observations points to the necessity of applying irrigation water before the subsoils become excessively dry, if a deep penetration of the water is desired. Just when this time arrives depends upon the cultural and irrigation practice which has prevailed during the winter and early spring. If the land has not been winter irrigated, or if a cover crop has been grown without adequate water, the subsoil may already be dried out below the wilting point by April 1. It is impossible to lay down any hard and fast general rule without examining the soil, and this brings us to the next point we wish to make: Every walnut grower should study and frequently observe the moisture condition of the subsoil as well as the surface soil in the walnut grove.

The subsoils can be examined and readily sampled by means of a soil auger. Such a tool can be made by any blacksmith and may consist of a two-inch carpenters' auger, welded to a steel rod, or a half-inch gas pipe. For the intelligent irrigation of a deeprooted crop like walnuts, a soil auger is as much a necessary part of the equipment as an irrigators' shovel.[24] Opposite sides of a given ten-acre tract may take water quite differently in the subsoil, while the surface soil seems uniformly irrigated. Only by the use of a soil auger can the farmer make any more than a poor guess at the soil moisture conditions throughout the deep root zone of the walnut tree. Figure 22 shows a farmer examining the subsoil in his grove to a depth of 8 feet, for the first time. Enough was learned from this one examination to convert him to the use of the auger henceforth.

The amount of water necessary to wet down through the root zone in a walnut grove will depend largely upon the type of soil and the degree of dryness which prevails before the water is applied. In general, it will require from 1¼ to 1½ acre inches per acre for each foot depth of soil, to bring the moisture from the wilting point or below, up to the normal field moisture-holding capacity of the soil. This may be taken as only a very general rule, however, as a clay loam soil which has been allowed to become very dry may require more than the above, while a sandy loam only moderately dried will require less. In any case, the farmer should study closely the movement of the irrigation waters in his own soils.

If, for example, he wishes to apply water enough on a sandy loam soil to penetrate downward 8 feet from the surface, it may require 10 acre inches per acre ($1\frac{1}{4} \times 8 = 10$) if the subsoil is dry, as well

[24] A soil auger has been designed by the Orchard Management Division, and is sold to walnut growers at cost by the California Walnut Growers' Association.

as the surface soil, at the beginning of the irrigation run. On the other hand, 6 acre-inches may be ample if the subsoil is not excessively dried. On land underlaid by clay or gravel within 8 feet from the surface, there is a likelihood that the root zone is correspondingly shallower than in the preceeding example.

Fig. 22.—A farmer examining the subsoil in his grove to a depth of 8 feet.

If the distribution of the root system of a crop justifies the practice of applying water sufficient to wet down to a depth of 8 feet, such a use of water at infrequent intervals will be more economical than frequent shallow irrigations. In the former case a smaller percentage of the total water applied will be lost by surface evaporation in the first 8 or 10 inches of soil. The frequency of irrigations desirable will depend upon the age and the number of trees per acre, the soil

type, the presence of intercrops, climatic conditions, etc., all of which comes back again to the necessity of each farmer "going to the bottom" of his own soil conditions with a soil auger.

Measurement of the water applied (explained on page 150) is as important as studying its movement through the subsoils to the farmer who wishes to learn the most about the moisture conditions of his soil and to improve his knowledge of the use the walnut trees are making of the water applied. It may prove a greater mistake in the end to apply too much water than not to apply enough. Water applied in excess is lost in the country drainage and may contribute to the rise of seepage water, to the eventual detriment to lands lower down, if not to the land in question. This may seem a far cry to many people who own groves where the ground water is now 30 to 50 feet from the surface. Such a rise of ground or seepage waters has occurred, however, through many valleys of the West where the ground waters were formerly 30 to 40 feet from the surface. Much, of course, depends upon the nature of the deep soil formations. It is sufficient now to say that the farsighted intelligent irrigator who looks upon his walnut grove as a permanent investment, will study the movement of soil moisture, not only throughout the root zone, but farther, and inquire into the possible loss of water by deep percolation beyond the reach of the walnut trees.

The actual method of applying the water to the soil must be adapted to the conditions of each case. Three different systems of applying water are illustrated by Figs. 19, 21, 23, 24, and 25. The advantages of the respective methods are briefly stated under each illustration.

INTERCROPPING

Intercropping the young walnut groves is a practice which prevails in a large majority of cases. This practice has usually proved very successful in making the land support the orchard before the walnuts come into profitable bearing.

The best intercrop to use will depend somewhat upon local circumstances. In the bean districts and in cases where the walnut groves are large enough to justify the maintenance of bean farm machinery, beans are an ideal intercrop for the young walnut grove. The bean is a legume and requires thorough cultivation. These facts contribute to the best conditions for the development of the young trees, if sufficient irrigation water is avaialble for both crops. The bean straw can be plowed under, which is an advantage of the bean intercrop over all others.

Fig. 23.—The furrow system is probably the most advisable way of applying water, if the water will move into the subsoil readily and the surface slope is such that it flows across the orchard satisfactorily, and without much "run-off."

Fig. 24.—If the land is check-furrowed at the lower half of the orchard, the run-off will be reduced and added pressure of deeper water in the furrow forces the moisture into the dry subsoil.

Outside of the bean districts, the choice of intercrops largely depends upon the market conditions for the proposed crops. Several of the vegetables commonly grown for canning factories may be profitably grown in the young orchard without harm to the trees. Such crops as tomatoes, peppers, and string beans are often used. Figure 26 illustrates a bean intercrop in a bearing walnut grove.

Intercrops of corn, milo, squashes, and pumpkins are not so well thought of among many experienced walnut growers, because of their apparently harmful effect upon the trees. Milo especially is generally considered a bad intercrop for walnuts. Milo is a very drought-resistant crop with a relatively low water requirement. It will therefore develop a first-class crop under soil conditions unfavorable to the best growth of the walnut trees. The thrifty appearance of the milo may deceive the farmer concerning the condition of the walnut roots. Only the closest students of irrigation should attempt to grow this crop in a walnut grove, and it may be of doubtful value even then.

If the grower has only a small plantation, not justifying the maintenance of bean farm machinery, and has not a ready market for a vegetable crop, the intercropping with a precocious bearing fruit tree may be desirable. Peaches, prunes, and apricots are among the fruit trees most commonly used in such schemes of intercropping. In many instances observed, the growing of these stone fruits in a young walnut grove has retarded the growth of the nut trees, when compared with groves interplanted with beans. Nevertheless, in many cases, the fruit trees have been profitable and have made the orchard self-supporting while the nut trees were growing, thus out-weighing, from a business point of view, the temporary check of the walnut trees. If fruit trees are used as an intercrop, the farmer must study his irrigation problem carefully to be sure the walnut trees are not robbed of their needed water by the companion crop. General observations indicate that the apricot tree is a keener competitor of the walnut than the peach, and thus less suitable to plant.

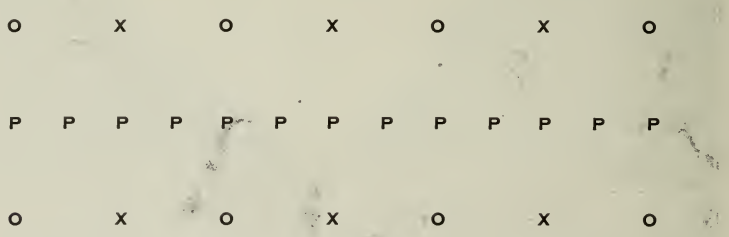
The disadvantages of intercropping the young walnut grove with fruit trees should be considered before laying out a plantation in this manner. The following are among the most serious objections. If the cling-stone canning peaches are used as an intercrop, they will require late summer irrigation to fully develop their crop, after watering should be discontinued upon the walnuts. This discordant water requirement will be most troublesome when the plantation is from three to six years old. At this period the owner is naturally anxious

Fig. 25.—Basin irrigation, with water standing six or seven inches deep over the land, insures its movement into the subsoil. This is especially practical on the level sandy soils. This system may also be used to advantage where the surface soils are very sandy and thus take water so rapidly that it is impractical to force a small stream in a furrow across the orchard.

Fig. 26.—Showing beans used as a profitable intercrop in a ten-year-old grove, in a bean-growing district.

to make the most of the first commercial peach crops, and some of the latest and most profitable varieties should be watered in late August and September in order to bring them to a good size for the canning factory. This late water on young walnut trees is very liable to keep the twigs growing so late that they will be severely injured by the early fall frost. Such a hazard will diminish as the walnut trees come into bearing and the drain of crop production acts as a regulator in slowing up the late summer growth and in thus aiding the walnut trees to become nearly dormant at the season of early fall frosts. The prune has been a profitable intercrop with walnuts, but here the discordant water requirements are somewhat reversed, and do not become pronounced until both the prunes and the walnuts are in bearing. At this stage in the development of the plantation, when it is possibly from six to twelve years old, and before it seems economically sound to pull out the prunes, the late summer water requirements are quite opposite with these two crops. As the walnuts mature they should be irrigated so that they will be fully developed and so that the husks will crack open, producing a clean-shelled, plump-kerneled nut; irrigation of the prunes at this time will also cause them to crack open and in so doing make an inferior product, liable to rejection by the prune-selling agencies.

If either prunes or peaches are used as interplants it would seem advisable to plant the walnuts 30′ × 60′ and the fruit trees in solid rows in the middle of the interspaces. These temporary trees might be planted only 15 feet apart in the row, which would give enough fruit trees per acre to make it worth while, and yet have room enough for heavy fruit production for a few years in this rather "hedge-row" planting. The following diagram illustrates this plan.



O Permanent walnut trees.
X Temporary walnut trees.
P Filler trees of peaches or prunes.

This arrangement would permit irrigating only a part of the land and thus serving the water requirements of one crop without affecting

its associate crop, or only slightly. As the trees grow older, the roots become interwoven throughout the entire soil mass and gradually the advantages of this plan lessen, and the filler trees should then be pulled out.

FERTILIZATION

The walnut crop makes relatively small demands upon the plant food of the soil in comparison to other fruit crops. This may be illustrated by Table VII.

TABLE VII

Plant Food Elements Withdrawn from the Soil by Various Fruits, Expressed in Pounds per Acre

Fruit	Amount of crop	Nitrogen	Phosphoric acid	Potash
Oranges	16,300 lbs.	28.23 lbs.	8.63 lbs.	34.39 lbs.
Lemons	18,900 lbs.	28.53 lbs.	11.52 lbs.	50.84 lbs.
Apricots	10,000 lbs.	19.73 lbs.	6.40 lbs.	29.00 lbs.
Walnuts	1,000 lbs.	10.20 lbs.	2.78 lbs.	1.50 lbs.

Very little definite information has been obtained on the subject of fertilizing walnuts since Smith[25] reported in 1912 the results of the fertilizer trials on the Cudahy ranch. In reviewing these results the author wrote as follows:

> The results of this experiment are typical of all experience in fertilizing walnuts. Many attempts have been made to determine the most effective practice in this respect, but all of these have shown no positive effect on account of variation in the trees and an apparent lack of response to fertilizers. In regard to walnut fertilization it is, therefore, impossible to offer definite advice based on actual experiments, but the most that can be done is to suggest such practice as may reasonably be expected to give good results with any crop on California soils. We know in general that nitrogen and phosphoric acid are our most needed elements and that the application of these substances, especially on older plantings, is almost certain to result in improved growth and vigor in almost any plant. We also know of the walnut, that individual trees produce as a general rule, in proportion to their size, and that the larger they become the greater crops they will bear. It is, therefore, our conclusion that in fertilizing walnuts, nitrogen and phosphoric acid should be the elements most largely supplied.
>
> Along with fertilization there should not be forgotten the importance of keeping the soil in good mechanical condition, especially in order that it may absorb and retain the greatest possible amount of moisture. Indeed, it is evident from the results of the Cudahy experiment, as well as from general observation, that this factor is much more important, at any rate for several years, than that of fertilization.

[25] Walnut Culture in California, Univ. of Calif., Experiment Station Bull. No. 231, 1912, p. 188.

Field trials with various kinds and amounts of fertilizers applied to several walnut groves are now being carried on by the University of California, coöperating with the field Department of the California Walnut Growers' Association. Although these trials have been in progress since the fall of 1917, definite conclusions cannot be drawn from this work at the present writing.

With the widely varying soil conditions which exist in the several walnut-growing districts, a uniform fertilizing program is not likely to be suitable to all. To be profitable, however, the excess due to the fertilizers must pay the added cost of the fertilizer, the labor of applying, and the labor of handling the increased crop. Each farmer should make a careful study of any fertilizer treatments applied to his own grove, in order to be able to judge of the economic soundness of fertilizing walnuts under his local conditions.

PRUNING

Unlike many of the fruit trees, such as apples, or oranges, the pruning of the walnut tree has not evolved into a very definite, systematic practice. In many groves no pruning at all is done except the cutting off of the lower limbs which interfere with cultural practice.

The fact that few walnuts are produced in the centers of the old trees, has suggested a moderate thinning out of the branches from year to year in an attempt to promote production more uniformly throughout the trees. Sunlight is necessary for the production and maintenance of fruit spurs, and, without some thinning out, practically all of the crop is produced on the outside twigs, in the tops, and on the sides of the trees. Some of the most successful walnut growers have adopted this sort of pruning as an annual practice, cutting out the water sprouts and the dead wood; thinning out the thickest growing portion of the top, and reducing the number of crossed limbs and weak crotches. In the absence of any results of systematic field trials this gradual and annual thinning-out process seems the most advisable.

This system of pruning should not include the heading back of the fruiting limbs, as such a practice will promote a rapid growth of water shoots near the ends of the parts which remain, defeating the very attempt to shorten the limbs. If the limbs are too long and top-heavy on the sides of the trees, they should be cut out entirely, or cut off to lateral limbs, thus restricting in a measure the development of water shoots.

In all pruning operations with the walnut, care should be taken to cut the limbs off smoothly with a saw without leaving any stub. All wounds of 2 inches in diameter or over should be painted with a weatherproof paint. The walnut wood decays very readily and therefore any large cut exposed to the weather for a short period will surely become infected and start a decay which will eventually spread to the center of the tree. The framework of the tree thus undermined by so-called heart rot, may be split by an overload of nuts, and partially or wholly destroyed.

It is expected that the pruning experiments now being carried on by the University of California in coöperation with the Field Department of the California Walnut Growers' Association will eventually give definite information on this subject.

INSECT AND DISEASE PESTS

Insects.—The only insects which are troublesome to the walnut industry are the *codling moth,* the *aphis,* and the *red spider;* these are mentioned in their probable order of importance.

Codling Moth and Aphis.—These two insects may well be considered at the same time, for, where they both occur, control methods for both may be combined in one application.

The codling moth has been known to attack walnuts in California since 1909, when it was first observed in the vicinity of Concord.[26] Since its first appearance, it has periodically become very troublesome in several of the walnut districts of southern California.

The injury caused by the codling moth to walnuts is similar to that seen in wormy apples. The worm eats a portion of the kernel of the nut and renders the remainder uneatable. The manner of attack and entrance of the worm is clearly shown in Fig. 27.

The aphis is a small green plant-louse which feeds on the leaves and succulent growth by sucking their juices. This weakens the tree at a critical stage, causes it to produce less crop, lighter and smaller nuts, and imperfect shells. The foliage of a tree infected with this insect becomes covered with "honey dew," a sticky secretion which turns black upon continued exposure to the air. The damage caused by the aphis varies from year to year. In some sections the damage is considerable every year, in others only in exceptional years. The aphis usually disappear with the approach of extremely hot weather.

[26] The Codling Moth in Walnuts. H. J. Quayle, Monthly Bull., Dept. Agric. California, vol. IX, No. 3, 1920, p. 64.

In discussing the control of the codling moth and aphis before the Third Annual Convention of the Walnut Growers at Whittier, California, in January, 1920, Professor H. J. Quayle of the Citrus Experiment Station made the following recommendations:[27]

THE CONTROL OF THE CODLING MOTH ALONE

Where the codling moth has been present in orchards in past years and the amount of infestation has been about 5 per cent or greater, the trees should be *dusted or sprayed with basic arsenate of lead between May 25 and June 20.*

1. *Dusting.*—Five or six pounds of dust[28] per tree is required for trees of medium size, and 7 to 10 pounds for the largest trees. A thorough application should be made to cover all the nuts on all parts of the tree.

2. *Spraying.*—Use 6 pounds of dry basic arsenate of lead to a 200-gallon spray tank. For trees of average size, 20 to 25 gallons of the spray per tree is necessary, or ¾ of a pound per tree of arsenate of lead. For the largest trees, 30 gallons per tree of spray is necessary, or $\frac{9}{10}$ of a pound of arsenate of lead per tree. All the nuts on the trees should be reached by the spray. It is not necessary to spray the trunk and branches or any part of the tree where there are no nuts. Spray guns should be used in order to reach all parts of the tree. Spraying will insure a higher degree of control of the codling moth than dusting, but the labor expense is somewhat more and it takes longer to cover a given acreage.

FOR APHIS AND CODLING MOTH

Where past experience has shown that the walnut aphis, as well as the codling moth, may generally be present in large numbers, use a dust combination containing both tobacco and arsenate of lead. If spraying is to be practiced instead of dusting for the codling moth, add one pint of "black-leaf forty" to each 200-gallon tank of arsenate of lead.

FOR APHIS ALONE

Where there is no codling moth, but the aphis is generally present in serious numbers, use Nico-dust, a material especially prepared for aphis control. From 2 to 6 pounds of this material is necessary per tree, according to the size of tree. The best general time for such treatment is during the last week of May and the first two weeks of June. During years when the aphis occurs in great numbers, it may be advisable to dust a second time, during July or August.

RED SPIDER

In some years the red spider does much damage to walnut trees in isolated instances. Injury is not usually apparent until the middle of the summer, when the leaves turn a dull but decided yellowish hue. A close examination at this time will show the presence of a countless number of red spiders, barely

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[27] From an unpublished manuscript.

[28] Arsenate of lead is mixed with kaolin, which acts as a diluent and a carrier. Use only the standard commercial brands.

visible to the naked eye. If the injury goes on unchecked, the leaves will drop prematurely, injuring the quality of the current crop and the development of fruit buds for the future crop.

The most practical control measure is dusting with dry sulfur and hydrated lime, three parts to one, respectively. Spraying during the dormant period has not been advisable in the past, because outbreaks of this insect have not been frequent.

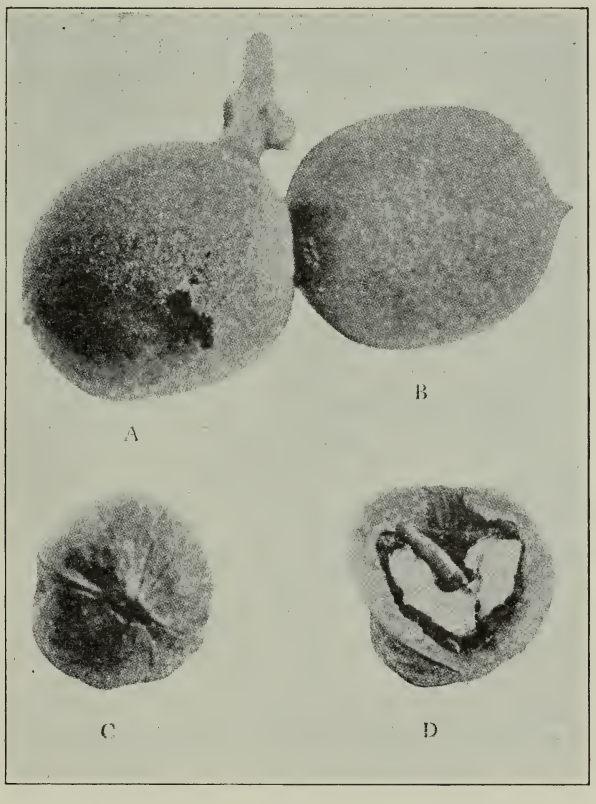

Fig. 27. (From "The California Walnut.")

(A) Appearance of green nut after worm has entered on open side. (B) Codling moth worm usually enters green nut on the stem end as here shown. (C) A round or oval opening on the stem end of the cured nut is almost a sure sign that the worm has paid his respects inside. (D) Section of walnut showing the codling moth worm.

WALNUT BLIGHT

The walnut blight is by far the most destructive disease affecting the walnut crop. The prevalence of this disease, as previously stated, varies considerably from year to year, and is usually much worse in the foggy coastal districts than in the inland valleys. In years of

bad outbreaks, the blight has probably destroyed from 15 per cent to 20 per cent of the crop. It is a bacterial disease which attacks the young and tender growth and spreads to the more mature wood, causing the affected areas to turn black and die. Under favoring conditions, the disease is especially destructive to the nuts. If it attacks the nuts early, it causes them to turn black and drop off when one-eighth to one-half of an inch in diameter. It causes mature nuts to remain undeveloped, and may make full-grown nuts unmarketable, except as culls. It shows on the nut as black spots most prevalent at the calyx end, but often scattered over its entire surface.

At present there is no control known for this disease. Attempts to lessen the prevalence of the blight by spraying and by the combination of spraying and pruning off the old blight cankers from the twig growths, have had no measurable effect upon the disease.[29]

Some of the varieties now being propagated are more resistant to blight than the average seedling tree. At present the greatest likelihood of relief from this disease lies in securing resistant or immune varieties.

MELAXUMA

This troublesome disease of the walnut tree has occurred in isolated and serious outbreaks in Santa Barbara, Ventura, Los Angeles, and Orange counties. Careful studies of this disease were made and reported in 1914 to 1915 by Fawcett.[30] The nature and treatment of the trouble may best be summarized by quoting from the above author. (For a detailed discussion of the disease, see the original publication.)

Because of the oozing of dark watery material to the surface of the affected areas, this disease is often confused, under the name of "black sap," with sunburn, frost injury, injuries to the bark in cultivation, injury from the decay of wood at places where limbs have been cut off, and other troubles in which a "black sap" may ooze out during the active growing period of the tree. It should not be taken for granted, therefore, that, because a black ooze is seen on the trunk or larger limbs of a walnut tree, Melaxuma is necessarily present.

As the term "black sap" has already been used by R. E. Smith to designate a result of sunburning, this name was not considered suitable for the disease here being considered. The word *Melaxuma*, derived from two Greek words meaning "black" and "juice" was therefore adopted, and is now in fairly common use to designate the disease herein described.

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[29] An Attempt to Control Walnut Blight. H. S. Fawcett and L. D. Batchelor. Monthly Bulletin, California Dept. Agri., vol. IX, No. 5–6. 1920.

[30] Melaxuma of the Walnut, H. S. Fawcett, Univ. of Calif. Experiment Station Bull. No. 261, 1915.

Description of the Disease

Melaxuma shows its effect most strikingly during the summer after the growth is well started. On trees severely affected at this time, there will be seen large black sunken cankers on the trunk and larger limbs and often a sudden wilting of the smaller limbs and twigs. This sudden wilting of the smaller limbs is so different from the effects of walnut blight or bacteriosis, that it is easily distinguished from that disease.

The most common location for Melaxuma cankers is at the crotch of the tree where the first limbs join the trunk. The first evidence of the disease is often a black area on the otherwise grayish bark which looks like a dab of tar, as shown by Fig. 28. This is due to the staining of the bark by a black watery substance that forms under it. The diseased area later becomes slightly sunken, shrinks, and cracks. The "black sap" then oozes out in considerable quantities and stains the bark as it runs down the limb or trunk. The wood underneath is discolored for a short distance and this discoloration usually extends beyond the margin of the killed bark. The diseased areas, as a rule, do not extend entirely around a limb in one season, but affect only about one-third or one-half the circumference of the bark. Later in the summer or fall the increase in the size of the areas is slower and often appears to be stopped. One part of the margin of the canker may dry out and begin to heal over, while the other continues to advance or remains stationary until the next spring, when it begins to advance rapidly again. A few cankers on large limbs of vigorous trees may even heal over without treatment. More often there is an enlargement from year to year which in two or more years extends entirely around a large limb, causing it to wilt and die. These limbs occasionally wilt suddenly, the dried-up nuts and leaves remaining attached for some time. When cankers occur on the trunks they generally follow some injury to the bark made by a plow, cultivator or other instruments used in the cultivation of the orchard.

From the observations and results of experiments so far made, the following tentative treatment is suggested:

Cut out the cankers that have not gone too far on the trunk and larger limbs and disinfect the wounds thus made. (See Fig. 29.) The dead and discolored bark should be cut away, getting a little beyond the margin of dead tissue. If the cankers are not large and the wood underneath has not been stained deeply, it will pay to dissect all the discolored wood as well as the bark. Probably one of the best disinfectants to apply to the wound is the Bordeaux paste,[31] that is recommended for lemon gummosis. If the canker is

[31] *Bordeaux Paste.* The formula for Bordeaux paste is as follows: 12 pounds of bluestone (copper sulfate) dissolved in 8 gallons of water in a wooden, earthern or glass vessel; and 24 pounds of quick-lime slaked in 8 gallons of water. When the lime is cool, stir together about equal parts by volume of each, for making enough mixture to last for one day only. The bluestone is most easily dissolved by suspending it in a sack at the top of the water over night. If the bluestone is pulverized and suspended in warm water, it dissolves rapidly. Good lime that is not air-slaked should be used, and after slaking it with the water, it should be allowed to cool before being used in making paste. If covered to avoid evaporation each ingredient will keep indefinitely, but after mixing, the paste slowly deteriorates. Where it is being used over a number of days or weeks, just enough of the wet slaked lime and the bluestone solution should be mixed to make paste enough to last for one day, leaving the remainder unmixed in separate vessels. It may be applied with large brushes, as in whitewash.

large and has been in the tree a long time, the wood may be stained so deeply as to render the work of cutting out all discolored wood too expensive. If the canker has practically girdled the limb, the limb had better be cut out.

WINTER INJURY OR DIE-BACK

This trouble of the walnut tree has been made the subject of considerable study by Smith[32] and Batchelor and Reed.[33] Perhaps it can be summarized best at this time by quoting from the last mentioned authors.

Winter injury or die-back of walnuts is characterized by a sudden death of the tops of the trees. Such injury is usually first noticeable during the early spring following the dormant period.

The most common causes of the winter injury or die-back are given below.

1. Early autumn frosts kill the immature, growing shoots. Young walnut trees are more subject to injury from this cause than older trees, because they are usually later in maturing their new wood. Such frosts cause the foliage to drop prematurely and injure the growing tips of the twigs. The denuded twigs are subject to further injury from subsequent fall and winter sunburn. The presence or extent of this injury is usually overlooked until the following spring.

To reduce the danger from autumn frosts it is advisable to withhold the late summer irrigation in order to promote the early maturity of the trees.

2. Winter drought causes die-back in either young or bearing walnut groves. Trees suffering from this condition fail to make new growth in the spring, except from the trunks or main limbs. The new growth on such trees has lost so much water during the winter that the buds are unable to develop in spring. The cause of the die-back has been found to be due to an extremely low moisture content of the soil during a large part of the winter. Under such conditions, the water lost from the young shoots during the winter cannot be replenished by the root system, and the shoots die from desiccation.

Fall and winter irrigation of the walnut groves has been found to eliminate the injury from winter drought. The amount of irrigation will depend upon the type of soil, the amount of soil moisture present at the end of the harvest season, and the rainfall which may be expected later in the season.

Figure 30 shows a walnut tree thus affected and afterward cured by winter irrigation.

The late fall or early winter irrigation of the walnut groves, especially in the inland valleys, may be looked upon as an insurance policy against this form of die-back. To be effective it should be applied in December and January. In some years subsequent rains will show that the die-back insurance policy was unnecessary. The

[32] R. E. Smith, Walnut Culture in California, Univ. Calif. Experiment Station Bull. No. 231, 1912, p. 372.

[33] L. D. Batchelor and H. S. Reed, Winter Injury or Die-back of the Walnut, Univ. of Calif. Experiment Station Circ. No. 216, 1919.

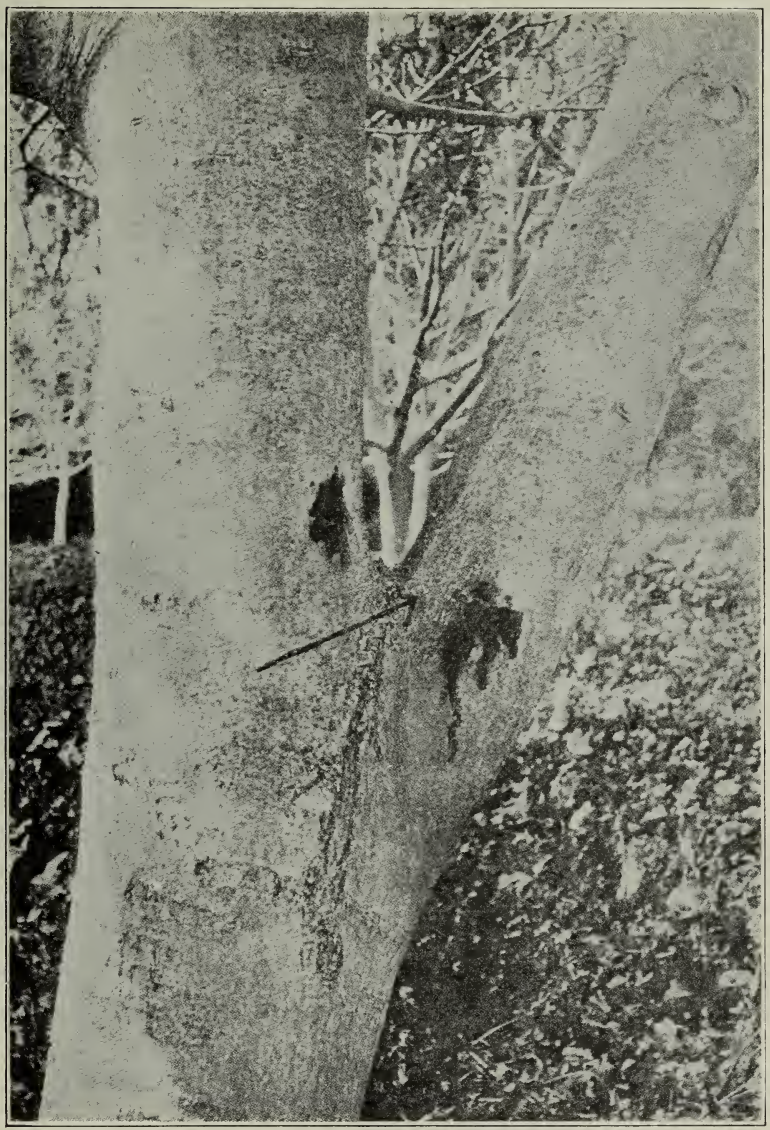

Fig. 28.—One of the first evidences of Melaxuma. The black sappy ooze has appeared at the outer edges of the killed bark at the crotch. The bark between has been killed and pycnidia of Dothiorella have already appeared on the surface of part of the killed bark. (From Fawcett, Bulletin 261.)

same apparent objection, however, applies to fire insurance on the barn or house, during the years that there are no fires on the property.

3. A high water-table may be a contributing factor in die-back. A permanently high water-table causes the trees to prolong their growing season, with the result that they are killed by frosts. The sudden rise of a fluctuating water-table may kill a large part of the root system and produce a typical die-back in the tops, even though the wood is mature.

4. Alkali soils containing such a high salt content as to injure the root systems of walnut trees, also cause the tops of the trees to die back in response to the root injury. In the initial stages of alkali injury, the leaves turn brown at the margin and fall prematurely. The denuded shoots sometimes put out a new set of leaves in the fall. The top of the tree gradually dies back until the entire tree is lost.

If injury is being caused by irrigation water containing too much alkali, obviously the use of such water should be discontinued.

HARVESTING, CURING, PACKING, AND COST OF PRODUCTION

HARVESTING

During favorable seasons and in well-cared-for groves the husks of the nuts crack open and adhere temporarily to the twigs, while the nuts drop clean-shelled to the ground. This natural dropping of the great bulk of the nuts occurs with most varieties between September 1 and November 7. There are usually enough nuts on the ground to justify the first picking by the second week in September. The natural falling of the nuts is hastened by the shaking of the trees by means of long poles with hooks attached to the ends.

During the harvest period the nuts are picked up three or four times before the total crop has matured and dropped. It is not considered good practice to allow the nuts to remain for a long time on the ground. Nuts thus neglected are subject to the work of ants in the kernels, and may be rained on by the autumn showers. The effect of rain upon the nuts may be entirely superficial if they are picked up promptly after they are dry again. At the best, however, they will be dirty and more or less stained, causing extra work of washing in preparing them for the packing house, and making proper bleaching more difficult. Nuts long neglected on the ground after a rain become mouldy and stained on the outside of the shells, especially those which have a portion of the husk adhering to them. If the stain of the mould is pronounced, it will be impossible to bleach it, and the nut must be graded as a cull. If further neglected, the mould from the outside of the nut may spread to the kernel, through the base of the nut, and thus lower the value even as a cull nut.

A certain percentage of the nuts will drop with the husks adhering to them. These are commonly known as "stick-tights" and are likely to be inferior to the clean shelled nuts in their plumpness and in the appearance of the kernels. There is usually a high percentage of

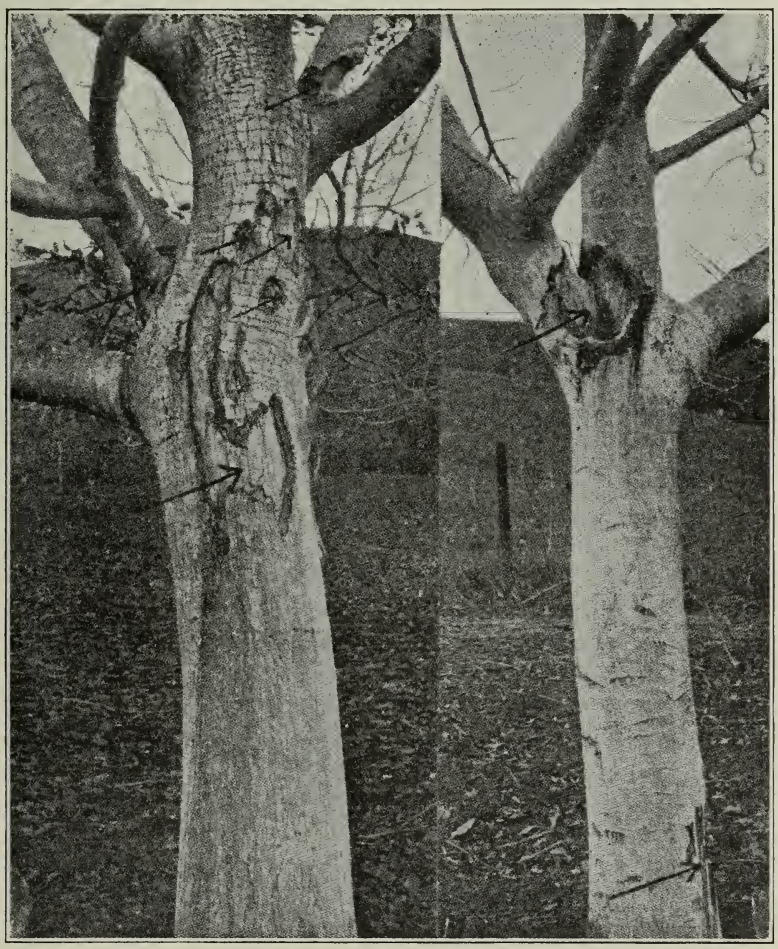

Fig. 29.—Walnut trees showing the location of Melaxuma cankers that had been cut out and treated with Bordeaux paste the year previous. Notice the rows of holes in the bark of one tree, made by sapsuckers. These probably served in this case as a partial means of infection. (Fawcett, H. S., Bulletin 261.)

blanks, shriveled, mouldy, and dark-colored kernels among the stick-tight nuts. The percentage of stick-tights is greater during seasons of abnormally high temperatures, when the nuts are sunburned and when the husks are affected with blight. Again, trees which suffer

from drought during the latter part of the growing period, or which are subject to the attacks of aphis, red spider, or for any other reason lose their leaves prematurely, produce a high percentage of stick-tights and inferior nuts.

In general, the stick-tight nuts are husked by hand, especially those on which the husks are actually green, although several large ranches have made devices to husk them by machinery. The portions of the husks which have dried on the nuts, as in the case of sunburning, and blighted husks, are removed by the washing machine, described later.

The nuts are usually picked up and sacked by Mexican and Japanese families who contract to perform this work.

WASHING AND CURING

After being picked up and sacked, the nuts are ready for curing. If the majority of them are dirty from lying on the ground during showers, it is necessary to wash them. This washing is done in large cylindrical drums made of coarse wire netting, in which the nuts are slowly revolved under a stream of water, grinding against each other and against the wires which form the sides of the drum. They are thus cleansed of all loose foreign material. This washing process will not remove the stains on the shells due to sunburned and blighted husks sticking to the nuts. There is practically no need for washing the clean-shelled nuts.

The curing is accomplished by spreading the nuts out in shallow trays, with bottoms made of slats spaced about one-half an inch apart. The nuts should not be left exposed to the sun during the entire day if the weather is especially clear and hot, for the drying will be so rapid that many of the nuts will crack open. If the trays are spread out in the morning and the nuts thoroughly stirred several times, the trays may be piled up when the nuts are well warmed up. The slow drying which goes on while the trays are in piles of course prolongs the length of the process, but is good insurance against the splitting of poorly sealed nuts and their rejection as culls by the packers. Figure 31 shows a yard full of trays ready to be piled up after being thoroughly warmed up by the morning sun. The trays should be so piled up as to allow ventilation between them.

If the walnut grove is large enough, it will save expense to use a "drying house" for the curing process. Such "dry houses" are built with outer walls of lath to give good ventilation as shown by Fig. 32. The drying bins are arranged one above another. The nuts are carried away from the washing machine by a belt and thence

Fig. 30.—Showing the effect of winter drouth and recovery of the tree two years later after irrigation.

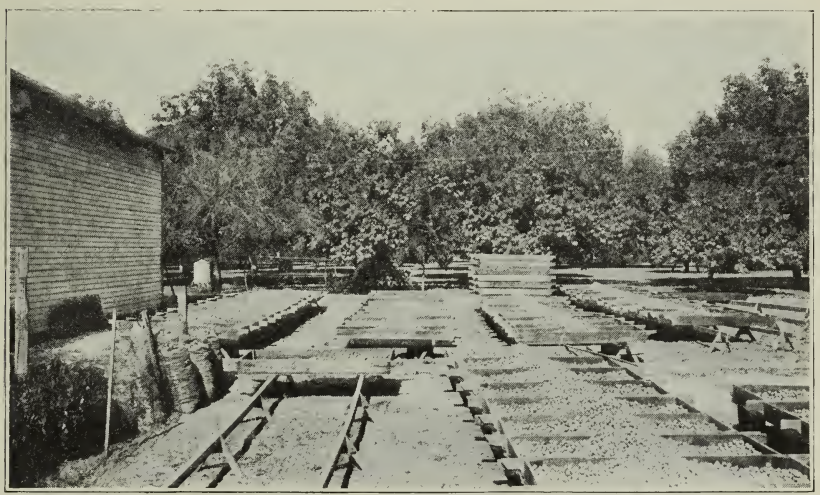

Fig. 31.—Drying walnuts by means of spreading them on trays placed on low racks.

elevated to the upper bin, as shown in Fig. 33. The nuts are dumped mechanically from one bin to the bin below it. Thus the nuts work through the whole series of bins from the top down. There may be seven or eight of these bins and by dumping them each once a day, the nuts will be passed through the house in seven or eight days. As the nuts leave the bins after this period, they are usually sufficiently cured to be ready to go to the packing house, to be bleached, graded, and bagged for shipment. If the weather is warm and the atmosphere very dry, the nuts may pass through the drying house in four or five days. Much will depend also upon the condition of the nuts when they go into the house, as well as upon the exposure of the house to breezes, sunshine, etc.

As the nuts pass along a belt when they come from the drying bins, or as they are sacked from the trays, they should be carefully sorted to pick out the culls. Nuts are thrown into this cull class if they are cracked, perforated, badly stained by blight or sunburn, wormy, or if a part of the shuck is adhering to the shell. The good nuts are now ready for the packing house, while the culls are kept separate to go finally to the cracking plant.

PACKING

Although the packing and selling of the walnut crop in California is quite distinct from its production, it is nevertheless desirable for each grower to know how his nuts are to be graded and packed, in order that he may realize more fully the importance of delivering high-grade nuts to the packing house. About 85 per cent of the walnut crop of California is packed and sold through the local houses which are affiliated with the California Walnut Growers' Association. It may therefore be proper to relate briefly the processes followed in these houses in preparing the crop for shipment. Mr. W. T. Webber has clearly described the stages of grading and packing in the words quoted below.

ELIMINATING IMPERFECT NUTS[34]

After being properly cured, the nuts are delivered to the local packing house by the grower, where they are first run over a rough screen which frees them from dirt and all foreign matter. From this screen the nuts pass through a suction machine, a device which lifts the blank or imperfectly filled nuts over a trap and allows the full-meated nuts to pass through. From the suction machine the full-meated nuts pass on to an endless belt where girl cullers, seated on each side, remove the ill-shapen and bad-appearing nuts.

[34] The California Walnut, 1919, pp. 47–57.

Fig. 32.—"Drying houses" are built with outer walls of lath to give good ventilation.

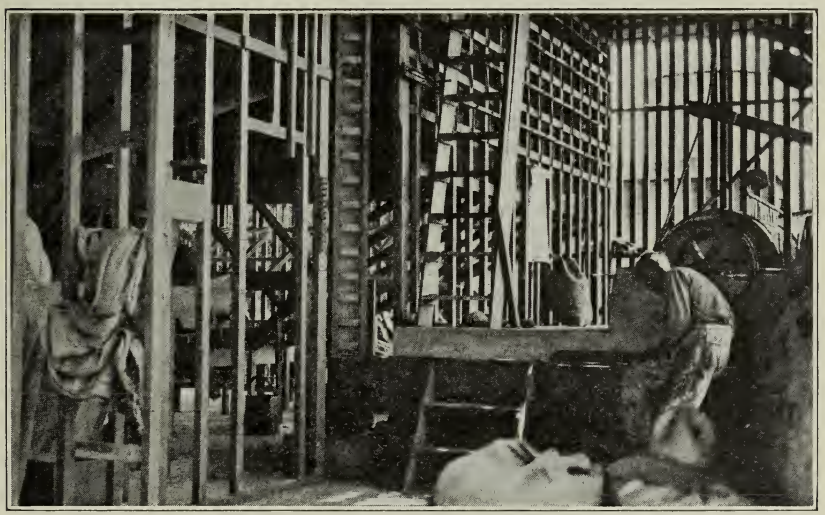

Fig. 33.—The nuts are carried away from the washing machine (shown in the right background) by a belt, passing before the inspector who removes the culls. Thence they are carried by the elevator, shown in the center, to the bins shown at the right center of illustration.

BLEACHING

The next treatment is that of bleaching. The nuts are given a bath of from one to two minutes' duration by passing them through large drums partially filled with a liquid bleaching solution, for the purpose of removing dirt and stain and brightening the appearance of the shells.

From the bleaching drums they are passed over another shaker which frees them from accumulated drops of the solution, and they are then elevated and graded to size.

GRADING

For this process large galvanized-iron cylindrical graders are used. Each grader is 10 feet long and 40 inches in diameter, set on a 6-inch pitch and has a capacity to properly grade one and one-half tons of walnuts per hour. A soft-shell walnut grader contains somewhat over 8000 $1\frac{1}{32}$ inch square openings and the walnuts which pass over the grader without falling out at one of these openings are known as No. 1 Grade. Those which fall out comprise the No. 2 Grade.

Budded graders contain somewhat less than 8000 $1\frac{3}{16}$ inch square openings, and the nuts passing over constitute the Fancy Grade and those falling through the Standard Grade.

From the grader the walnuts again pass on to a grading-belt, where those that have not been bleached properly, or have been broken by the bleaching and grading operations, are removed. The perfect nuts then go into the drying-bins, and after a period of from 24 to 48 hours are packed, 100 pounds net weight, in burlap bags, ready for shipment.

THE STANDARD FOR FIRST-GRADE NUTS

A nut is considered satisfactory if its size is in accordance with the specifications for the No. 1 or the No. 2 grade; if its kernel is plump and sound, not too dark in color; if it is not wormy, mouldy, or rancid; and if one portion of the shell has not split and fallen away from the other. The shell must have no material outward blemish and must show a clean bright color.

In most seasons the California Walnut Growers' Association guarantee that at least 90 per cent of the nuts in each sack sold by them comply with the above standard.

SELLING THE CROP

As noted heretofore, about 85 per cent of the walnut crop is sold by the California Walnut Growers' Association. This central organization is a non-capital, non-profit, coöperative association, composed of approximately forty local packing associations. The local associations are also organized on the coöperative principles. The local plants grade and pack the nuts of their members in accordance with the standard agreed upon by the central association. The central association, by a rigid inspection, maintains the standards set and performs its prime function of selling the crop. The walnut growers, affiliated as above noted, thus receive the actual selling price of their nuts minus the bare cost of grading, packing, and selling the nuts.

The walnut growers who do not belong to the coöperative associations usually sell their crops to the various independent packing firms, who later grade and pack the nuts according to their own standards.

INCOME TO BE DERIVED FROM CALIFORNIA WALNUTS

In order to assist the beginner in considering the probable profits to be derived from growing walnuts the following table has been prepared.

The average yield for the state varies from year to year. Numerous statistical publications indicate that a ten-year average yield for bearing orchards is approximately 800 pounds per acre. It follows, therefore, if an orchard is picked at random the chances are even that the average yield for ten years is 800 pounds or less. This figure has been used as a conservative estimate for business purposes in the calculations below.

Goodspeed[35] found from a survey of nearly a thousand groves that the cost of operation of a bearing grove was approximately $50.00 per acre under conditions similar to those set forth in the following table, exclusive of depreciation. This figure has been increased slightly from the above mentioned calculations in order to cover depreciation and, in the especially heavy producing groves, to also cover the extra cost of harvesting big crops.

Hunt[36] writes that, "A competent farmer should expect, and no one should undertake to farm unless he may reasonably expect, to produce 50 per cent more than the average. On this basis, the gross income per annum may be estimated at 25 per cent of the capital invested. This does not mean that every legitimate farm enterprise will, or should bring in just 25 per cent of the capital invested. This statement is only meant to give one a 'yard stick' with which to measure any definite farming enterprise."

The average annual gross income from walnuts, as shown by the preceding table, amounts to approximately 19 per cent of the capital invested. This does not necessarily mean that the table indicates an inflated capitalization of the industry, because this return has attracted adequate capital to the walnut industry in competition with general farming, owing to the facts that walnuts have required less investment in farm machinery than many other crops; the trees are long-lived, and therefore there is a smaller annual depreciation than

[35] "The California Walnut," published by California Walnut Growers' Association, 1919, p. 20.

[36] "Suggestions to the Settler in California," T. F. Hunt, Univ. of Calif. Experiment Station Circ. No. 210, 1919, p. 4.

with many fruit crops and animal industries; walnuts are less perishable during the harvesting, packing, and marketing operations than many crops; and the annual prices of walnuts received by the growers have gradually increased during the past twelve years, without any great speculative fluctuations from year to year.

ESTIMATE OF THE AVERAGE RETURNS WHICH MAY BE EXPECTED FROM CALIFORNIA WALNUT GROVES

	Safe estimate for business purposes	Income which competent men may hope to obtain	Possible, but extraordinary
Yield per acre	800 lbs. (approximate average in California)	1200 lbs.	2000 lbs.
Valuation per acre	$700.00	$1000.00	$1700.00
Gross income per acre[1]	130.96	196.44	327.40
Annual cost of operation per acre[2]	$ 55.00	$ 60.00	$ 70.00
Annual cost of packing and marketing, per acre	16.00	24.00	40.00
Total charge per acre against crop	$ 71.00	$ 84.00	$110.00
Net income per acre[3]	$ 59.96	$112.44	$217.40
Interest at 4% on valuation[4]	28.00	40.00	68.00
Profit per acre[5] (Above what might have been realized, with the capital invested in safe securities and the owner working out for wages).	$ 31.96	$ 72.44	$149.40

[1] Based on selling price of No. 1 nuts for ten years, 1907–1918 (16.37 cents). All nuts would not be No. 1, therefore, the above returns are slightly exaggerated.

[2] Includes irrigation, pruning, cultivation, harvesting, depreciation and taxes.

[3] Gross returns minus all expenses.

[4] The rate of 4 per cent is used here to charge against the grove as the return which might have been made had the owner invested in securities rather than a walnut grove. This rate of interest is in harmony with investments made with a minimum of risk and a minimum of skill and effort on the part of the investor.

[5] The gross returns minus all expenses and 4 per cent of the valuation of the property.